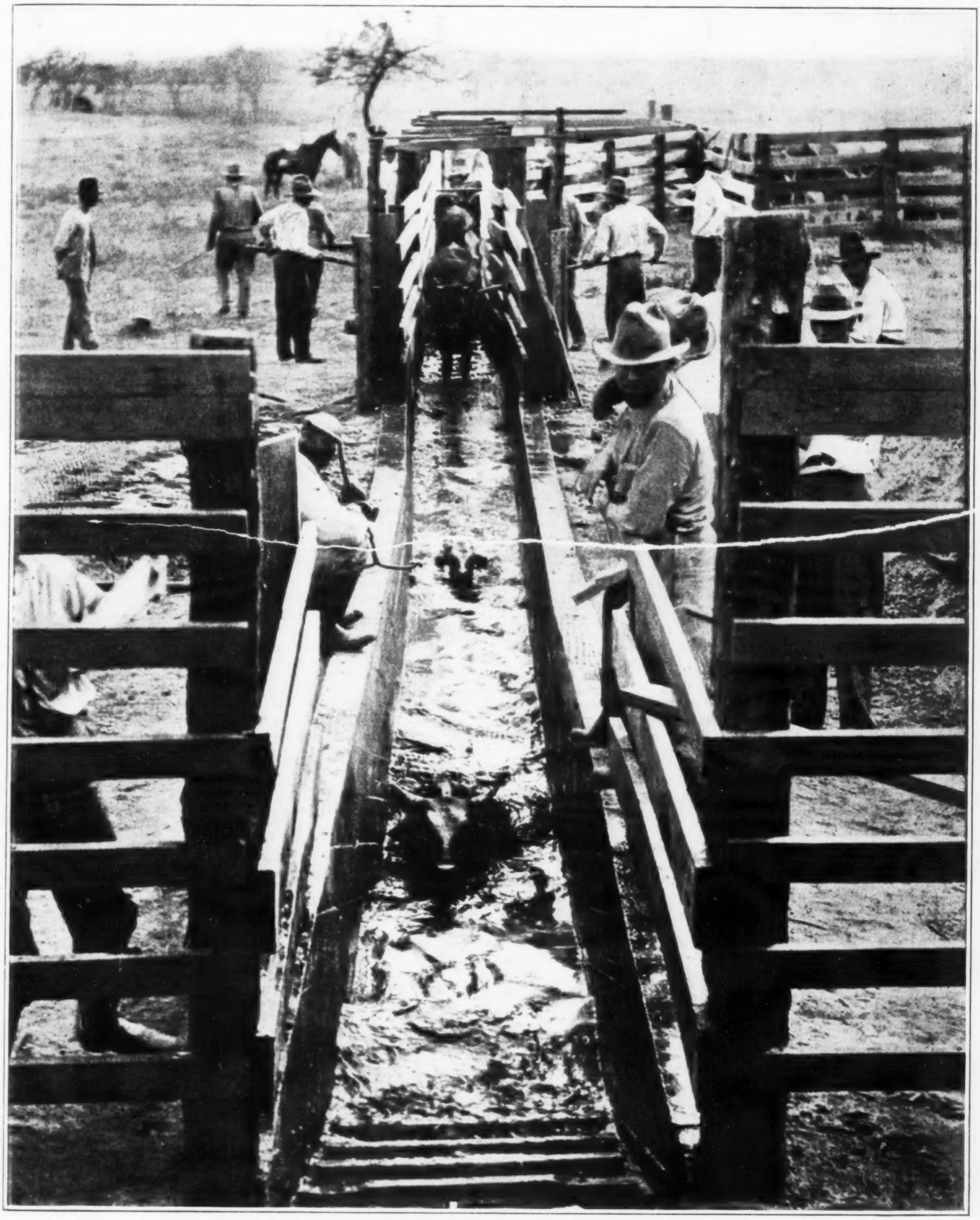
SCIENTIFIC AMERICAN SUPPLEMENT

VOLUME LXXXVII
NUMBER 2264

NEW YORK, MAY 24, 1919

Published weekly. Entered as second class matter December 15, 1887, at the Post Office at New York, N. Y., under Act of March 3, 1879

10 CENTS A COPY
$5.00 A YEAR



Cattle passing through a disinfecting tank to destroy insects that cause Texas or tick fever

SAVING OUR CATTLE (see page 328)

Stellar Evolution*

An Attempt to Correlate Two Outstanding Problems of Physics

By William Duncan MacMillan

There are two questions at the present time which are of fundamental interest to astronomers and physicists. The first question is, What becomes of the enormous flood of energy which is poured forth so lavishly by the sun and by the stars? Does it travel unendingly through the depths of space until it strikes some material object, or does it not?

The second question is, What is the source of the enormous subatomic energies which have been revealed in recent years by the radioactive elements, and which by implication exist in all of the other elements?

In the first question we ask, What becomes of this energy? In the second, Where does this energy come from? Surely such a situation is not so embarrassing as it would be if we had but one of these questions, for an infinite source or an infinite sinkhole of energy is scarcely to be thought of. The two questions seem mutually to answer one another, and it seems reasonable to conjecture that the energy which disappears from the sun and stars into space reappears sooner or later in the subatomic energies of the atoms.

One may suppose that the physical universe is finite or that it is infinite, for it is not possible to verify either supposition. The idea that the physical universe is finite is doubtless repugnant to most minds that have dwelt upon the subject, and we therefore reject this supposition. The distribution of matter in space may be roughly uniform or it may be distinctly non-uniform. Again we are at liberty to make either supposition, for neither can be verified. But if we assume the universe to be infinite, then unless the distribution of stars is non-uniform of a special type the entire sky should glow with a brightness equal to that of the sun's disk. Certainly this would be true if radiant energy is not extinguished in its course through space.

It is quite possible to distribute infinitely many stars in such a manner that the total quantity of light received from them should be anything we please. For example, imagine a series of concentric spheres of radius 1, 2, 3, . . . n, . . . and on the surface of each sphere is placed a number of stars, the number being equal to the integral part of the square root of the radius of the sphere. If the amount of light received from the star on the first sphere be taken as unity, then the entire amount of light received from all of the stars would be less than

$$1+\frac{1}{2^{3/2}}+\frac{1}{3^{3/2}}+\frac{1}{4^{3/2}}+\frac{1}{5^{3/2}}+\ldots .$$

whch is finite, but the number of stars in the system would be infinite. In any such distribution, however, the average stellar density approaches zero as the distance becomes sufficiently great. While such distributions of stars are possible, they seem so highly improbable that we reject them and seek some other explanation of the blackness of the night sky.

There is no recourse save in the hypothesis that radiant energy is extinguished in its course through space. If we assume that there is a uniform distribution of stars and that the stars are all alike, there should be four times as many stars in any given magnitude as in the magnitude next brighter. The actual star-counts, however, show that while this ratio is maintained between stars of magnitude one and magnitude two it falls off steadily until between magnitudes sixteen and seventeen the ratio is only 1.8 instead of 4. Is the decline in the number of stars due to the extinction of light in traversing these enormous distances? It is a simple matter to assume that a certain percentage of radiant energy is lost in traveling through space and to test the hypothesis by an appeal to the star counts. Obviously the stars do not all emit the same amount of light; that is, they are not all of the same absolute brightness. Thus the star AOe (N) 17,415 is only 0.004 times as bright as the sun, while Canopus cannot be less than 10,000 times as bright as the sun (absolute magnitudes, of course, being understood). Thus between the faintest known star and the brightest known star there is a ratio of 2,500,000 or sixteen magnitudes (absolute). Assuming that the stars are distributed over fourteen magnitudes (absolute) in accordance with the law of probability, and that 1 per cent. of light is extinguished in traveling 4.11 parsecs (13.6 light-years), the following table has been computed showing the number of stars or the various relative magnitudes on the hypothesis of uniform distribution of the stars in space. The actual star-counts of Chapman and Melotte of the Royal Observatory at Greenwich are given for comparison.

Mag.	Star Counts	Computed	Mag.	Star Counts	Computed
6	2,026	2,201	12	961,000	960,200
7	7,005	7,135	13	2,023,000	2,080,000
8	22,550	21,770	14	3,964,000	4,210,000
9	65,040	62,230	15	7,824,000	8,034,000
10	172,400	166,200	16	14,040,000	14,420,000
11	426,200	413,400	17	25,390,000	24,510,000

Certainly there is nothing in these figures to forbid us from supposing that the blackness of the sky is due to the extinction of light in its journey through space; and the amount of the loss (1 per cent. in 13.6 years) does not seem excessive.

But what becomes of the energy which is lost? Is it permissible to suppose that the light is intercepted by dark material scattered through space? It is clear that the effectiveness of dark material in cutting off light is increased by supposing it in a finely divided state. If it is supposed that the dust of space consists of particles one one-hundredth of an inch in diameter it is found that one such particle to every 560 cubic miles of space would be sufficient to account for the 1 per cent. of loss mentioned above. This does not seem to be an excessive amount of dust particles, and yet a continuation of the computation shows that in the 40 cubic parsecs which, according to the foregoing figures, is the sun's share of space, there is 6¾ times as much material as there is in the sun itself, and if the particles average one-tenth of an inch in diameter there is 67.5 times as much material as in the sun.

It may indeed be true that such dark material exists in space, but nevertheless it cannot account for the blackness of the sky, because the energy which it intercepts is either retained or radiated. If it is radiated, then there is no change in the total amount of radiation; at most merely a change of wave-length, since the amount radiated is the same as the amount intercepted. So far as the total quantity of energy is concerned the result is the same as though the dark material were transparent. If the energy be retained, then the dark material would eventually become hot and would itself be bright. One concludes, therefore, that dark material in space cannot account for the blackness of the sky.

The accepted notion that radiant energy suffers no loss in transmission through a dust-free ether is not analogous to other physical processes, for in the physical world "perfection" does not seem to be attained. Perfection is an intellectual ideal, comfortable only so long as it represents the known facts with an approximation sufficient for our purposes. If we confine ourselves to a sufficiently small portion of the earth's surface we may be well satisfied with the hypothesis that the earth's surface is a plane, for the facts encountered are in close agreement with our hypothesis; but in a larger field of operations the curvature of the earth's surface is thrust upon us and cannot be ignored. So with the transmission of radiant energy it may be quite accurate enough to assume that there is no loss in such distances as are encountered in the solar system, but appreciably wrong when the distances encountered are of interstellar dimensions. According to Kapteyn the average distance of the first magnitude stars is 75 light years. We have a right to be cautious in extending our hypothesis of "perfection" in the transmission of radiant energy into regions in which 75 light-years is the unit of distance.

If dark material seems inadequate to diminish the total amount of radiation, we may have recourse to the absorption of energy in the ether. But the energy cannot be absorbed without doing work, and in casting about for some sort of work which this lost energy might do there occurs the possibility that it is here that the foundations of the atoms are laid, and perhaps also the completed structure.

Let us assume that absorption does occur and attempt to construct a model to illustrate how the kinetic energy of the ether-waves might be converted into the potential energy of an organized system.[1] Imagine a number of spheres floating on the surface of the ocean. Imagine further that on these spheres there are springs, and that at the bottom of each spring there is a hook. As these spheres are tossed about by the waves there will be frequent collisions, followed in general by an immediate separation. Occasionally, however, two spheres will collide in such a way that when the springs are compressed the hooks are engaged, and separation does not follow. The two spheres are locked in tight embrace, and we have the beginning of an organized system. The energy of the compressed springs was absorbed from the energy of the ocean waves, though the amount of energy absorbed was perhaps relatively small. The two spheres thus joined would, in the course of time, unite with other spheres, and thus an organized system would be built up and the internal energy of the system would have been derived from the ocean waves. It is not necessary, indeed, to dwell upon the details of such a process. Through the agency of chlorophyll it is known that the radiant energy of the sun is absorbed and locked up in the organized systems of the vegetable world, though the mechanical details of the process are quite unknown. In a manner analogous to the organic molecule, and by a process the details of which are quite unknown, we may suppose that the ordinary atom comes into being and that the familiar properties of inertia and gravitation are due to the energies locked up within. Disrupt the atom and set its energies completely free and the properties of mass and gravitation at once disappear.

Important consequences follow the admission that atoms are built up in this manner. It would follow that space contains much material of atomic or even molecular dimensions, and that regions long undisturbed by stellar objects would tend to become more or less crowded with atoms and molecules on account of the ceaseless passage of radiant energy through it. In this manner we see the genesis of a nebula with its enormous gravitational and subatomic energies. A sufficiently large mass in its journey through space would gather in this atomic and molecular material and feed upon its substance and energies. It would be a nucleus around which material would gather. If this nucleus were relatively small and dark, such as the earth, its growth would be slow; the subatomic energies would persist as subatomic energies, and the mass would increase. In the course of time the internal pressure, density, and temperature would increase, and one can imagine that a critical situation would eventually be reached in which the subatomic energies can no longer wholly persist as subatomic. The atoms begin to break down and give up their stores of energy. In the event of a complete dissolution of the atom we would expect the complete disappearance of its mass and a complete restitution of the energy by which it was organized. If the dissolution were but partial we would have the familiar radioactive phenomena and a partial restitution of the subatomic energies. The energies thus released would raise the temperature of the nucleus and presumably hasten the process of disintegration. The density would decrease until, if the mass were large enough, the increased molecular energies would convert the once solid nucleus into a gaseous sphere. If the mass continued to grow after a completely gaseous state had been reached, the increased gravitational pressure would cause the density again to increase, and this increase with a growing mass would continue until eventually again a critical state would be reached of heat and pressure, and the release of subatomic energies would be so great that the gaseous mass would begin to glow. A further increase of mass would again hasten the process of dissolution accompanied by a rise in temperature and a second decrease in density, and the process could continue, as far as we can see, until the tenuity of a nebula was attained. If the various bodies in our own solar system, with whose masses and densities we are familiar, be arranged according to their masses, it is found that they do conform to these ideas, as is shown in the diagram (Fig. 1). Thus all of the planets and satellites which are smaller than the earth are in a solid state and their densities increase with an increase of mass. Somewhere between the mass of the earth and the mass of Uranus, which is fourteen times the mass of the earth, there would exist a mass of maximum density beyond which a solid mass cannot persist as wholly solid, and there begins a transitional state between the solid and the wholly gaseous condition, and in this transitional state we find the planets Uranus and Neptune. Saturn, with a mass equal to 94 times the mass of the earth, seems to have attained a wholly gaseous condition and has the smallest density of any object in the solar system. The mass of Jupiter is 3.3 times the mass of Saturn and its density is about twice that of Saturn. There are no bodies in our solar system intermediate between Jupiter

*From the *Astro-Physical Journal*.

[1] It is not essential, perhaps, to suppose that there is an ether. Some other process would answer our purpose; but it seems preferable to use the current concepts of physics.

and the sun, but it is not difficult to imagine that somewhere in between the increased mass and increased density would again produce an internal condition in which the production of heat would be so great that the mass would begin to glow and that relief from this state of excessive energy would be found in a decreased density. Thus the sun, which is in the very midst of stellar conditions, has a density but little in excess of that of Jupiter notwithstanding its enormous mass.

When the stellar condition had been reached by a growing gaseous mass, the radiation of its energies into space would afford relief to the imprisoned atoms, tending to check the disintegrating process. Eventually there would be an equilibrium between the energies furnished by the process of dissolution and the energies expended in radiation and gaseous expansion against gravitation. If the process of gathering up atomic and other material from space were discontinued, the mass of the star would diminish, its volume would shrink, and its density would increase. The temperature eventually would fall and the critical state would be passed again, but this time in the direction of a return to the pre-star state. There would be relief from the excessive pressure and temperature which had brought about the release of subatomic energies, and a return to the dark state would be possible.

It is not necessary, however, to suppose that the ingathering process is stopped. If it continued at a suitable constant rate an equilibrium would be attained between the income and outgo of energy, the energies of radiation would be continued, the mass would remain constant, and it would endure as a star forever. If in its wanderings the star passed through a region unusually rich in material, its mass again would grow and its temperature would rise until it attained the white brilliancy of star of spectral type A or B or in the extreme case pass into the nebular state, in which the internal energies are gravitational-potential rather than the kinetic energies of heat. If it is assumed, as is natural, that in such a vigorous process of dissolution there would be a large residue of hydrogen and helium, we can account for the peculiar character of the spectra of stars of these types, for, owing to the lightness of these gases, they would rise to the surface and form an extensive envelope surrounding the brilliant star itself.

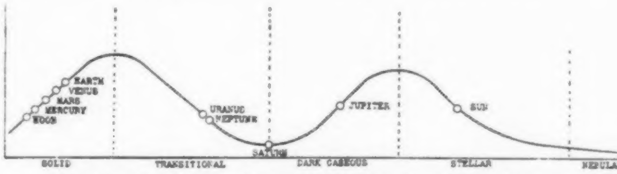
In connection with the point at which we have now arrived, W. W. Campbell has made the following observations:[2]

"The class B stars and the stars containing bright lines are where the planetary and irregular nebulæ exist. Going further into detail: wherever there is a great nebulous region either in or near, or outside of the Milky Way you will find the class B and earlier types of stars abnormally plentiful; and the chances are fairly strong that some of the stellar spectra will contain bright lines. This is true of great regions in the Milky Way; it is true of the Orion and Pleiades regions, which we see at some distance outside of the Milky Way structure, though they are doubtless within our system. If you see a wisp of nebulosity near a bright star, look up the star's spectrum and you will probably find it an early class B, as in the case of Gamma Cassiopeiae, a second-magnitude star, with nebulous structure near it whose spectrum contains both dark and bright lines of hydrogen and helium. If you see an isolated bright star enmeshed in an isolated patch of nebulosity, and books say the star (BD–10°4713) is yellow, or of class G, communicate your suspicions that the books are mistaken about the star's spectrum to Professor Pickering, and he will probably reply that the star is in reality a very blue one of early class B. That is what happened a fortnight ago about this particular nebula and the star near its apparent center. If you find a red or yellow star of normal type do not look for a nebula in apparent contact with it. Nebulae and red stars do not coexist. You will find about the same number of red stars in the Milky Way that are visible in similar areas far from the Milky Way. You will find an occasional red star in the region of the Orion nebula and of other large nebulae, but the red stars will not appear there in greater numbers than their approximately uniform distribution over the sky requires.

"The connection between the nebulae and the bright line stars and between nebulae and the early class B stars is close, both as to their types of spectra and as to their geometric distribution."

Just as the kinetic theory of gases shows that there is a lower limit to the mass of a planet which can retain an atmosphere, so the present considerations suggest a lower limit of mass to a star which can emit light, and possibly also an upper limit to the mass of a star beyond which the star passes into a nebula. An exact correlation between the mass of a star and the intensity of its radiation would be expected only for those stars in which there was equilibrium between the energies released and the energies radiated. A star growing in mass with relative rapidity might lag in temperature, owing to a possible time element in the release of subatomic energies; and likewise a star decreasing in mass might remain for a long period relatively too hot. But on the whole one would expect an increase in temperature with an increase of mass until the kinetic energy of the molecules became so great that the star tended to pass from the gaseous to the nebulous stage. This would mean a decline in internal pressure and in radiation, although the internal energies, increasingly of the potential form, were exceedingly great. The increase in the mean free path of the molecules and the decline in internal pressure would tend to check the release of subatomic energy, and in the extreme nebular state this release may virtually cease. In this manner one is led to imagine a maximum mass beyond which a star, as such, cannot exist. If nebular radiation be left out of consideration, a maximum of stellar mass would imply that there exists a maximum of stellar radiation. Although different stars vary enormously in the amount of their *radiations* their variations in *mass* are not excessive, at least if we may judge from the few masses which are definitely known.

If in its early stellar stage a star is of red color, one would expect to find a class of red stars of relatively small mass, viz., those masses which have been slowly growing toward starhood. On the other hand, stars which are condensing from a nebula of large mass would present a class of red stars of large mass. The kinetic theory of gases would lead us to doubt the possibility of a nebula of small mass, or a nebula of very low density, even though the mass be large, ever condensing into a star through its own gravitational attraction. Thus, *if all the mass* in the solar system were a spherical nebula 10 times as large as the orbit of Neptune, its velocity of escape would not be less than the velocity of escape on the moon, and it is well known that the moon cannot retain an atmosphere. It would seem that such a nebula would dissipate rather than concentrate. A third class of red stars would be those which were approaching extinction or passing into the dark gaseous state. If the main source of stellar radiation is the subatomic energy,[3] and if these energies are completely given up so that the atomic mass disappears, then one would expect those stars which are approaching extinction to be of small mass. If the various chemical elements have different critical conditions of temperature and pressure for the release of their subatomic energies, the mass of a fading star would depend upon its chemical constitution, and so also would the mass of a young star. While this variation of composition would permit a variation in the mass of such stars, on the whole one would expect them to be small and of high density. One would expect, further, red stars of small mass to show considerable variability in their luminosity, owing to the cataclysmic nature of the process of changing from one physical state to another. These anticipations with respect to the red stars are quite in harmony with our present knowledge of this class of stars.



The density of the principal bodies in the solar system as a periodic function of the mass

It is natural to suppose that atoms which are formed by the flow of energy through space would have little or no velocity at the time of their formation, and that the recently formed, irregular nebulae would have low velocities. On the other hand, nuclei of stellar types which have long been of stationary or of decreasing mass would have relatively high velocities, owing to the differential gravitation of all the stars exerted over enormous periods of time. During the process of its growth, however, a star would be increasing its mass without increasing its momentum, since the momentum of the added material would be approximately zero, and therefore its velocity would be decreasing. If the surmise that a growing mass means an increase in the rate of the release of subatomic energy is correct, then the growing star would push its way through the various spectral types toward class B with an ever-decreasing speed, which is quite in harmony with our knowledge that stars of class B have low velocities and that higher velocities are associated with the stars of deeper color. It harmonizes also with the knowledge that the stars of class B are on the whole the massive stars.

So also a star of class B which was produced from a recently formed nebula would have a low velocity, and this velocity would increase through the ages, owing to the gravitational action of other stars. But in the meantime, as it radiated away its energies and decreased in mass its spectral type would change in the direction from B toward M, so that again there would be an association of the deeper colors with higher velocities. Obviously, the same star may at one time be increasing in mass and decreasing in speed, and at another be decreasing in mass and increasing in speed, the spectral type changing correspondingly, and these changes may be repeated indefinitely. In view of these possibilities, then, we cannot assign an upper limit to the duration of the life of a star; nor indeed could we say that a star has but one life, for it is quite conceivable that its life may be extinguished and renewed many times.

One can imagine that a wandering star finds its way into a nebula of sufficiently enormous expanse and has its velocity so decreased that it is unable to escape. Another star, and still another, is entangled in its filmy substance, and finally a whole group of stars are brought to rest within its borders. If these stars come from all directions at random, the moment of momentum of the group would be small. Since the moment of momentum of the nebula itself would be small, there would be little tendency for the system as a whole to rotate, but under their mutual attractions these stars would take the form of a globular cluster. In the course of time they would sweep up the nebulous material which had bound them together; and this material for many ages would furnish the energy for their lavish radiation. But eventually it would be exhausted and the stars would decline in mass. As they did so, the gravitational control of the group on the individual members would be relaxed. The cluster would expand, and finally, one by one, the stars would escape and pursue their lonely journeys in search of new adventures.

An unusual epoch in the existence of a star will occur when it happens to pass through the immediate neighborhood of another star, an event which is almost certain to occur in a sufficiently extended period of time. The results of such an encounter are studied in the well-known researches of Chamberlin and Moulton on the planetesimal hypothesis of the development of our own planetary system. In this hypothesis the fundamental assumption is that at some remote epoch in the past our sun, even at that time a star, passed close by another star and that our planetary system has grown up and developed from the material which was torn from the sun by the tidal and disruptive action of the second sun. If the life of our sun is limited to some such period as a thousand millions of years it must be admitted that the chance for its encounter with another sun during this relatively short interval is small, and this objection has been urged. But if the time limit on the duration of the sun's life be removed, such an encounter becomes very probable, indeed almost a certainty, and our confidence in the planetesimal hypothesis is strengthened.

But if the sun is living upon material which is drawn in from surrounding space, the planets, too, at a smaller rate, must be adding to their masses and therefore growing, since they have not yet reached a stellar condition. In the course of time they too will grow to the full stature of a sun unless in the meantime the mutual perturbations of the planets shall have brought about the destruction of one or more of them through collisions among themselves or with the sun. Obviously the growth of the planets in such a manner would result in greatly contracting the dimensions of the planetary orbits, not only through the gravitative effect of increased mass, but also because the ingathering process would have much the same effect as friction, since the process would add nothing to the momentum of the planets and would therefore decrease their speeds. It seems quite likely that the road to stellar condition would not be traveled very far before the terrestrial planets would be swallowed up by the sun, and, if the sun also were growing, by the time it had arrived at spectral type B the sun and Jupiter only would be left to

(*Continued on page* ~~330~~.) 336

[2] "Address of the Retiring President of the American Association for the Advancement of Science," *Science*, xiv, 545, 1917.

[3] According to the hypothesis of the present paper the energy, or heat, obtained from gravitational contraction is merely energy which has been absorbed from the star itself on some previous occasion during a process of expansion against gravitation. In the long run no energy is obtained from this source, though it serves admirably as a reservoir of energy which can be drawn upon during times of famine.

A group of Havasupai about to patronize the sweat-house

Cataract Canyon, Arizona, where the Havasupai live

A Miniature from the Past

Dwellers in Arizona Today Who Appear To Be Left-Overs from the Stone Age

In recent years explorers have penetrated to the uttermost parts of the earth. These expeditions combined with the many and varied means of rapid modern communication over long distances linking up the nations of the world have made the globe seem like a small and thoroughly well known place today.

Nevertheless it is a fact that even yet explorers do occasionally return home with some very unexpected results in the way of discovery of new people, new animals and even now and then of new continents.

Stefansson's recent return from the Arctic recalls that he discovered the so-called "blonde Eskimo." During another expedition, in which Colonel Roosevelt prominently figured, the famous "River of Doubt" was placed on the map and then there was the great Congo Expedition under American auspicious which penetrated through little-known negro kingdoms into the heart of the Black Continent and brought back to civilization several heretofore unknown animals.

Now Mr. Leslie Spier, of the American Museum of Natural History, New York, has just had the unique experience of observing a truly primitive people living at this very time not in the heart of darkest Africa but right here within the boundaries of the United States, the little-known Havasupai Indians of Arizona.

These Indians are still what may be called a savage tribe and in most particulars are not much further advanced in their manners and customs than our remote ancestors of the Stone Age. They have been almost totally passed by in civilization's westward march on this continent, principally because of their inaccessible location.

As strange a story as in the children's wonder books is the tale of this lost wild tribe. Few indeed are the white men who have ever to this day penetrated to their village, and even the younger Indians distinctly remember the very first white man who descended to their canyon home. They live in the bottom of Cataract Creek, a gigantic chasm which joins the Grand Canyon of the Colorado in western Arizona. The nearest trader's store is 120 miles away, and a nearly waterless desert lies between it and the precipitous trail into the narrow canyon. The canyon walls are 3,000 feet high—four times the height of the Woolworth building with sheer sides to which the horsetrail clings until it plunges in zig-zags down a corner of the wall.

The Havasupai are ignorant of the use of matches and still light their fires by rubbing sticks together and less than ten years ago they were using exclusively stone heads for their hunting arrows and stone implements in their different occupations and to an extent use them still. They are so far behind the times that they have but little idea of money or its value and have no regular use for it among themselves.

Because of their isolated position, they are almost entirely without communication with the outside world; wars may wage and dynasties tumble as they have during the past four years without their knowledge. They have never been warriors, because they have always been numerically weak. Hostile raids into their canyon home have been ineffective because of the difficulties of ingress. They are as simple, friendly and intelligent a people as those Columbus discovered when he landed upon the shores of the New World.

Yet with all this the Havasupai village is one of the few entirely self-supporting communities producing everything for its own needs within our country's boundaries. There is a very good reason for this as the canyon bottom is a perfect oasis in the semi-dessert which covers northern Arizona. Here great fields of corn, beans, squash and fruit including the fig are raised. Wild seeds and cactus are gathered on the surrounding mountains in which deer, antelope, mountain sheep, and wild turkey abound, everything needed to well support the tribe. A large traffic in native produce is still kept up with the neighboring tribes who are also somewhat isolated, and until the most recent period these Indians had practically no relations whatever with the white settlers encroaching on their hunting grounds.

While they have characteristics of other tribes well known to Indian students—the Pueblos, Mohaves, and Plateau people—at the same time they are entirely individual and their exact origin is unknown.

It is a small tribe with only about 175 members now and according to their traditions there never have been more than 250. There is a scarcity of women between 20 and 40 and a number of widowers with children. Altogether there are thirty-eight camps or family groups with several houses in each.

On the top of the plateau from which one descends to the Havasupais there is a country of pine forests. Going down one passes through the arid regions, and on reaching the bottom of the canyon finds the fertile oasis just mentioned.

Before Mr. Spier visited the Havasupai he first sent a representative to them, a friendly Indian who understood their language, to learn if they would be willing to receive a white visitor. They replied they would

The good old-fashioned way of making a fire

The Head Chief and his wife decked out in their finest

be very glad to welcome such a guest.

The next proplem was to get there, the only entrance to their canyon is by a precipitous trail, the rocks forming great 100-foot steps, the final 500 feet being down a vertical wall on which the visitor has the appearance of a fly. This difficulty of entrance has for years prevented the visit of friends and foes and has kept the people a lost tribe.

Mr. Spier is a young man and well knows what roughing it in the West means, but he did not undertake the journey down the 3,000 feet of steep sheer rock surface of the canyon without considerable fear and misgivings as to whether he would ever reach the bottom.

However he made the trip without mishap and the Indians welcomed their guest as a special ambassador from another world. He spent a month and a half with them in what was an almost undiscovered country.

A storage plant out of reach of the floods

The tribe lives in brush huts of the crudest nature as much as they live in anything, for the climate at the bottom of the canyon is very mild, and it is only necessary to go inside when it rains. One of the tents was assigned to Mr. Spier. His own blankets served for a bed. The household equipment of the people is slender. They have a few cooking utensils of their own manufacture and baskets serve for table service as well as for many other purposes.

Winter quarters in a cave high up in the cliff

They take a basket, make it fireproof with cactus juice, and put their corn in it together with hot coals, and shake the basket to parch the corn. All their meats are dried and the explorer never could tell one from the other, but always had to ask what it was. They have no fixed times for meals and eating is more or less a continuous process, the pot being always on the fire, and the housewife stirs it with a spoon made of antelope horn.

The Indians eat from baskets, deep square trays, all the family eating from one tray, taking up the food with the fingers or with the native corn bread. According to Mr. Spier these Indians could give the average American housewife many tips in reference to the preparation of corn dishes. In fact he affirms they have an almost endless variety of them and nearly all are exceedingly palatable. One of these corn products which was new to the explorer was made of green corn mashed, made into patties and cooked in corn husks. Mr. Spier affirms that it was delicious. However what he considered one of the best dishes of these Indians was made from squash blossoms boiled like spinach with mashed corn.

They use very little salt and were amused that their white visitor needed so much of it. They do not use salt sparingly because it is scarce as it is one of their native supplies, rock salt being gathered by them in any quantity desired at the Grand Canyon.

Unlike those of some other more civilized Indian tribes the women of the Havasupai are well treated, nor are they called upon to do all the work as both the men and women work side by side in the fields, but the labor is not hard as things grow almost spontaneously in the fertile lands at the bottom of the chasm.

Perhaps the women work more continuously than the men as they are also the cooks, but they are not overworked.

The men hunt a little, not much, trade a little with other tribes, and the women make baskets—that is a sort of fancy work of theirs, and both the men and women gamble in a sort of fantan played with native dice. They play for different articles, money having but small value in their eyes which is not curious when it is remembered that in their canyon home they have nothing to spend it for.

Mr. Spier is of the opinion that although the least civilized, the Havasupai are the cleanest of all our North American Indians. The Sweathouse is the social club of the place. The men use it constantly and the women go in sometimes with either a husband or a brother.

Every one has a sweathouse and two or three are usually going at a time. One of the men will say to another, "Let's go over to So-and-So's and have a sweat," and a group will gather here and there. Four seemed to be the sacred number of the tribe. Four would go into the sweathouse together, come out and plunge into the creek and then dry off and go in again until they had been in four times. They dry off between sweats, sitting outside, and that is the time for gossip.

The explorer's housekeeper and the brush mansion in which he was entertained

The sweathouse is a small, almost airtight hut, with a hot stone on which water is thrown to make steam. It is pitch dark, and when Mr. Spier went in he was glad to have some one with him, the gloom being almost terrifying in the intense heat. The men wear simply a breechcloth in going in and the women a double apron.

For musical instruments the people have drums and rattles, and for recreation, besides gambling, they have dances. In the fall when the crops have been gathered they have a big harvest dance which lasts for several days. The walls of the canyon in which these Indians live, are filled with caves in which Mr. Spier is of the opinion there once lived a prehistoric people who may or may not have been the ancestors of these Indians. The tribe now use these caves as storehouses and also as a place of protection in inclement weather, in case of floods, which are at times serious in their bottom lands. The tribe is thrifty and has always a year's store of grain on hand in case of the loss of a crop by the torrents.

While Mr. Spier was with them last summer one of these floods came. It was in midday when the men were in the sweathouses. Suddenly the explorer was startled to see his interpreter dart past him, in the sweathouse garb, calling in the Supai language:

"Here she comes; run for the cliffs." He then gathered up a child in one arm and grabbed the mother, whom he pulled after him.

This was a cloud burst, and three children, many huts and a third of the crops were lost. In the caves in the cliffs the people are safe and when the water subsides they again return to their lowland homes.

The climate in the canyon being so mild for a greater portion of the year the Havasupai do not really need much clothing and for what they require they principally depend upon deerskins.

Recently however some of the most venturesome of the young men of the tribe have gone to the upper earth to work as cowboys and during these trips they have secured some second hand white man's garments in which they proudly attired themselves on state occasions. Mr. Spier when he arrived in the canyon, was surprised to see the old chief of the tribe dressed in a semi-civilized costume and prepared to receive him with all due honors. After these ceremonies were over the dress of the white man was however quickly discarded by the old Indian who stated he believed the breechcloth more comfortable and certainly cooler.

Industrial Substitutes in Germany

Since April, 1915, no cottoon has been used in the manufacture of smokeless powder in Germany, its place being taken by cellulose obtained from German woods. Camphor, which up to seven years ago was imported from Japan, was then replaced by a product made synthetically from American oil of turpentine, but when the importation of this oil was stopped, the whole of the camphor required for explosive purposes was prepared from German materials. It is claimed that the new synthetic product is cheaper and better than that derived from oil of turpentine. A substitute for manganese in steel was discovered in February, 1916, and has been used ever since. New works for the production of the ferro-manganese substitute are also in course of erection. The introduction of nettle fibres as a substitute for cotton in textile fabrics has given excellent results, especially when they are spun with a small proportion of cotton waste.—*Weltwirtschaft Zeit.*

The Significance of Dreams*

The Freudian Theory of Psycho-Analysis Illustrated

By Eugenio Rignano

Editorial Note.—This critical note by the well-known editor of the Italian Synthetical Review of Science "Scientia" (Bologna) is based upon a recent work by J. H. Coriat, *The Meaning of Dreams* (Heinemann, London, 1916), which sets forth and illustrates very clearly and synthetically the theory of Psycho-analysis as formulated by Freud and his disciples.

The psycho-analytic school founded by Freud has, as we know, raised the dream to the dignity of an instrument of research adapted to be made use of in the discovery of certain sentiments and desires which are either innate or date from the earliest infancy and which are in any case the most intimate and personal emotions possessed by every individual—sentiments and desires which do not ordinarily make themselves known because they are repressed or inhibited by other sentiments and desires, which are antagonistic to them and which have their source either in education or in social life in general. According to this school dreams represent nothing more than the satisfaction, realized by means of the imagination of one or another of these repressed desires. According to this view, therefore, they lose their futile aspect of states of consciousness dominated entirely by the mechanical and fortuitous process of the association of ideas (governed only by the well known laws of contiguity, simultaneousness, and resemblance, which in the last analysis can all be reduced to the single law of partial coincidence), and acquire on the contrary the profound significance of furnishing the explanation of an emotional life more intimate and more genuine than that which manifests itself in a waking state. According to the head of this school and the most eminent of his disciples these intimate desires which are in operation in dreams may even be said to be exclusively, or at any rate predominately, of a sexual nature; this idea, however, is so one-sided and exaggerated that it has been abandoned even by many psychologists who belong to this school of thought.

If the matter be reduced to the following formula i. e., to the affirmation that to the free play of the association of images which are purely intellectual (and it cannot be denied that in many instances this is not exclusively or even mainly the case), it is sometimes necessary to add those latent desires which become active solely during the dream precisely because they are no longer inhibited by the antagonistic or absorbing emotions of the waking state, and which evoke images both of desire and fear and guide the whole dramatic action of the dream, then I say, we cannot withhold from the Freudian school the credit of having added one more valuable instrument of research to our systems of psychological analysis. This school, however, has been guilty both on the part of its founder and even more on that of many of his disciples of such wild exaggerations that they have threatened to entirely discredit even the very real contribution made by it to the science of pyschology.

The first prejudicial opinion which has arisen with regard to this school is a result of the somewhat metaphysical concept of the "subconscious mind" propounded by the psycho-analysts. They behold it almost like a second personality included within our ordinary personality and as being almost our enemy in fact—as being always awake, never surfeited, always ready to escape, and with the will to satisfy its unsatisfied desires as soon as the ordinary personality quiets down in sleep. But even if we admit that there may enter into the dream some of the most intimate emotional tendencies and desires quite distinct from those of the waking state, the case is entirely different from that of a double personality. True cases of double personality may be either pathological or physiological, the latter being represented by the common instances of states of abstraction of thought during which the individual may walk towards his place of destination without running into passers by or being run over, though having his mind occupied the whole time with other affairs, and it must be admitted that in such cases both of the emotional or "effective" states which direct the simultaneous actions of the two personalities, are themselves *simultaneously active;* as regards those emotional tendencies, on the contrary, which are revealed during sleep and by their controlling influence upon dreams, we are bound to suppose that they exist normally "in the potential state," and do not become active except when the emotional tendencies which control us in the waking state have passed into the potential state. Thus there is no struggle between the "conscious mind" and the "subconscious mind," but merely the peaceful entrance of the latter upon the scene when the former has passed into a state of slumber. There is a struggle between the double personality, on the contrary, in certain pathological cases, more especially that of hysteria, which we shall refer to further on.

The psycho-analysts exaggerate, moreover, when they pretend that *all* or *nearly all* the desires which are innate, or which arise in any manner whatever during our earliest infancy, and which are later suppressed by the new moral sentiments created in us by education and by civilized life, are preserved unaltered though in the potential state, in our psychological life. We are forced to believe, on the contrary, that sentiments and desires, like sensory memories, completely disappear, even as regards a mere potential state, if they remain too long unrevived. Consequently, we may consider as highly artificial, or even completely fantastic, certain explanations of dreams based upon sentiments and desires of more or less secondary importance which the individual may have felt occasionally or which it is arbitrarily imagined that he felt in the first years of his infancy. This is the case, for example, with those very ordinary dreams in which we dream that we are partially or entirely naked, or that we are flying, or that we are losing one of our parents. Before the rise of the psycho-analytical school these were explained very simply as follows. It was said that the dreams of nakedness were to be explained by the absence of the constraint caused by the clothes worn during the day, that the flying dream was caused by the lack of the pressure against the soles of the feet which we feel when standing or sitting, and finally that the dreams of death were occasioned by the survival in the memory of the anxieties regarding a beloved parent which often oppress us by day until they are driven away by the sight of the said person in obvious good health. The psycho-analysts, on the contrary, pretend to give these dreams a more "profound" explanation. They connect the first two kinds of dreams with the intolerance with which we regard while infants the social restrictions which are imposed upon us, or with the innate desire of liberty, and they connect the third kind with the ill-feeling which some chance punishment or fit of jealousy has caused us to experience towards one or the other of our parents at a very tender age.

The artificial character of some of these interpretations is emphasized by the subsidiary hypothesis to the effect that these latent desires which come to life while we are asleep instead of satisfying themselves merely by the direct exercise of the imagination make use of a tortuous symbolism, the design of which is to prevent too free a revelation of the things we covet. It is quite obvious that by such a procedure we can make a dream mean anything we please. For example, a woman dreams about a child seated on the back of an elephant. The explanation is one of the simplest offered—namely, the woman would like a child but she is of ripe years and realizes at the same time that at her age a child would be a great burden; hence when she dreams of an elephant she is merely symbolizing this burden. In another dream the dreamer saw the lady of the house where he was visiting suddenly hide under the table, crouching down in a manner which was in violent contrast with her usual serious and dignified attitude. This was explained by the theory that the dreamer desired to be on terms of closer intimacy in the family, so that the lady would feel free to treat him without ceremony and thus would be willing to have him oftener as a guest.

These two examples, which are cited as specimens of this kind of explanation in the volume which has inspired these remarks, show sufficiently well the artificial and arbitrary character of certain psycho-analytical interpretations, according to which the celebrated "subconscious mind" is supposed to have recourse to an extravagant symbolism, instead of fulfilling its suppressed desires directly by means of the imagination. But this school is not even content with such far-fetched symbolism. To make even more difficult the interpretation of dreams they have devised theories of "condensation" and of "displacement."

In virtue of the first each element of the conscious content of a dream is supposed to result from the superposition and the fusion of a large number of component elements which are furnished by the subconscious mind. Thus, for example, an unknown countenance which makes its appearance in a dream might result from the condensation of four faces: that of an adored young girl, that of a lady of one's acquaintance, that of a pupil of the dreamer, and that belonging to the portrait of an actress. In virtue of the second process an element which is of minimum value in the subconscious mind may be pushed forward, so to speak, to the first rank in the dream and thus appear to be of great importance, while an element of the greatest interest for the subconscious entity may appear in the dream under the modest aspect of an insignificant detail, and the task of the psycho-analyst consists accordingly in employing all his sagacity to trace it and throw it into high relief.

And as if all this were still not enough this school assumes the operation of another factor, namely, the work of the "censor." This so-called "censor" is that element which is supposed to be responsible for the fact that the subconscious mind instead of fulfilling its desires directly and frankly by the help of the imagination finds itself obliged to resort to such tortuous and fraudulent processes as the ones just mentioned: symbolism, condensation and displacement. The ordinary consciousness of the dreamer, namely, that which is active in the waking state, becomes somnolent without being entirely asleep during the state of slumber; and without always having sufficient strength, as it has by day, to entirely repress the desire which is struggling to find expressioin, it still has a sufficient amount of resisting force to oblige the subconscious mind to satisfy its desires, not by the royal highway of simply imagining the objects and the facts desired, but by the winding by-path of symbolism, condensation and displacement. In other words there is supposed to be a sort of struggle between antagonistic emotional tendencies, a struggle which ends by disfiguring and deforming the intellectual process of ideation, constructed with the object of satisfying one of these tendencies.

The psycho-analysts even go so far as to maintain that without the work of the censor, i. e., if the subconscious mind were able to satisfy itself by the royal road of imagining the direct accomplishment of its desires, then the consciousness of the sleeper would instantly awaken him, thus interrupting the restorative action of slumber. According to this theory, therefore, the complicated mechanism of the dream (to which is due the absurdity found in most dreams) has for its object not only the satisfaction of the subconscious mind but the deception of the ordinary conscious mind of the sleeper and the eluding of the surveillance of the censor so that the sleeping individual shall not awaken, thus enabling the restorative processes of sleep to continue undisturbed.

Thus we see that while the majority of psychologists explain the absurdities of dreams by referring them to the setting at liberty of the mechanical and fortuitous association of ideas, because of the non-emotional condition of the sleeper (which thus arrests the work of inhibition and the control of emotional tendencies which operate in the waking state), the psycho-analysts, on the contrary, perceive in every dream, no matter how futile and bizarre, a sort of oracle capable of unveiling the profoundest arcana of the human soul, but lending itself also, like all oracles, to the most arbitrary and the most fantastic interpretations.

We repeat, however, that there is and there will remain something of fundamental truth in these bold theories, because the associationists have truly too much neglected the action which may be exerted in dreams by certain emotional tendencies, which ordinarily remain in the potential state, but which rouse themselves during slumber when the tendencies of the waking state are deadened; it is also true in general that the associationists have too much neglected in their consideration of all psychological facts and processes, the effect which may be exerted by the emotional portion of our psychological entity upon the intellectual portion, and it is not to be denied that certain morbid states, certain forms of hysteria in particular, have sometimes found an adequate explanation and a correspondingly successful treatment in the psycho-analytic theories concerning the origin of dreams; for if a dream represents (as according to these theories), the way of escape of a repressed desire, certain neuroses, especially those of a hysterical nature, must be due to the absence or the insufficiency of this safety valve, whence springs the psychological devastation caused by an emotional tendency which suddenly imposes itself

*Translated for the Scientific American Supplement.

imperiously upon the normal emotional life, after having been long repressed. But while we may acknowledge that there is something real and true in these psycho-analytical theories, they are so disfigured by the one-sided and extravagant character of the applications made of them, and so buried under the mass of arbitrary and fantastic interpretations of the most futile dreams, that one is tempted to reject the true along with the absurd, and this would be an unfortunate mistake. We conclude, therefore, that we have here a striking case in which to apply the ancient adage: *Cum grano salis*.

And making use of these principles, which are always incomplete though never spurious, one makes his judgment with the same assurance as if all his psychological property were at his disposal. Consequently the intellectual or moral quality of the judgments he forms depends exclusively upon chance: thus it may be admirable at any given moment but give way the next instant to the most absurd or abominable decisions through the lack in the conscious mind of one or another moral or logical idea or the failure to perceive some necessary contingent or accidental fact.

Let us consider a few examples.

In the dream of the two clocks the reasoning is quite correct and even rather ingenious so long as the elements which it brings into play are sufficiently complete. It will be observed, however, that I estimated the length of the arc extending from St. Germain des Près to the Montparnasse Railway Station at several degrees because at the moment I thought that the diameter of the earth was only a few hundred meters long, being temporarily deprived of all knowledge of its real length, which had I been awake I could have easily recalled; in the same way I thought that the large hand of the clock made only one revolution about the dial in twelve hours, because I knew, in fact, that this is the ordinary speed of one of the hands but I forgot for the time being that it is the small hand and not the large hand which moves at this rate of speed. So much for logic. Let us now consider a question of fact. In my dream of the poisoned dog I felt a tender concern over the fate of a short haired yellow fox terrier because the appealing expression of his eyes made me take him for my little dog Nina, forgetting that the latter was black and had long hair and that consequently this terrier could not be she. All the facts of the incorrect recognition in dreams which has been so much discussed can be explained in a similar manner. In the mind of the sleeping Egger[1] let the image of a blond young man with a timid air arise and at the same time the idea of Gambetta appear, drawn forth by another association, and the dreamer will take the young blond to be Gambetta. And the intellect of Egger will utter no protest concerning the improbability of this false recognition because everything which might indicate its falsity is for the moment absent from his mind. We now come to moral ideas. In the dream of the Garibaldian the reason why M. K. felt no disgust in committing sodomy upon the execrated person of Napoleon III., was because there was absent, for the moment, from his conscious mind the sentiment that such an act would be doubly odious, both because of its nature and because of the subjects it brought together. Let us close our argument by the fact in the realm of simple common sense. The reason why Bernard Leroy[2] in his dream of the symbolic bell tower took a church tower to be a young girl and felt no surprise at seeing the said tower take its seat at the banquet table was because there was absent for the time being from his conscious mind the common-sense idea that a tower could not be a young girl and sit down at the table.

We have said enough in the preceding pages to be now able to state the psychological definition of the dreamer in a few phrases which will serve to conclude this work.

The dreamer is a sufferer from partial but not systematic amnesia, and the field of his memory is both limited in extent and constantly variable in form, in contour, and in localization. He makes correct use of the materials which are within his reach and all the mistakes which he makes, whether in the realm of fact, of good sense, of logic, or of morals, are due not to any vitiation of the functioning of his mental faculties, but merely to the circumstance that all the ideas which might enable him to avoid such mistakes are temporarily absent from his conscious mind. Unlike many sufferers from waking amnesia he is entirely ignorant of his own amnesia, and acts at any given time as if there were nothing in the universe outside those ideas which are actually present in his conscious mind. . . . And he is consequently deprived of all capacity to explore the domain of his memory with reference to points which are for the time being outside the field of his consciousness.

The conditions of the war suggest to me a comparison which admirably illustrates these incessant variations of the field of consciousness in the course of dreams. When the airplanes of the enemy are sighted the siren sounds its warning and the searchlights come into play, whereupon we observe a luminous spot moving capriciously about, lighting now one portion of the sky and then another while all the rest remains dark. This luminous spot always in motion represents the psychological consciousness of the dreamer, while the dark remainder of the sky stands for all the residue of his psychological property, which is for the time being entirely outside his consciousness. His psychological universe is reduced to this small illuminated area, which is always in motion and never the same.

APPENDIX.

Dream of the Two Clocks.—In this dream I seemed to be in the Rue de Rennes on the balcony of a house not far from the Rue du Vieux-Colombier; I turned my gaze to the right and saw the clock of St. Germain des Près facing me (which is contrary to the real state of affairs). I saw that it was a quarter to eleven; I then turned my head to the left and my eyes fell by chance upon the dial of the clock upon the Montparnasse Railway Station. Upon this the hands indicated ten minutes to eleven, whereupon I said to myself "Why is the time different on these two clocks?" I began to reason about it as follows: "One of them," I said to myself, "is doubtless badly regulated;" then suddenly an admirable idea popped into my brain. "How stupid I am," I said; "it must be due to the difference in the meridians. But does this difference in the hour really correspond to the difference of the meridian?" In order to find this out, instead of computing the distance of the two clocks from each other, I took, as I thought, the radius from each of them to the centre of the earth, and since the earth appeared to me to be much smaller than it really is, I was not at all astonished that these two radii made a perceptible angle with each other, and that this angle was exactly 30 degrees in magnitude like that of the large hands of the two dials. At first I was quite satisfied with this discovery, but then an objection rose in my mind. I said to myself, "The hand of the clock goes twice round the dial while the earth makes a single revolution, hence the angle should be twice as large upon the dial of the clock as upon the earth; since it is merely the same size there must be an error in the regulation of the clocks just as I thought at first."

It will be seen how precise and correct was the process of reasoning which I pursued in this dream, although at the same time I was guilty without perceiving it of a triple absurdity: First, that of estimating the difference in longitude between the two clocks at 30 degrees; second, of comparing the movement of the earth not to that of the small hand, which really travels twice as fast, but to that of the large hand which travels twenty-four times as fast; and third, because in any case the clock of the station would have been slower and not faster than that of St. Germain, since in my dream I saw the former exactly west of the latter, this idea doubtless being due to the fact that whenever I take the train at this station it is always in order to travel westward.

Dream of the Poisoned Dog (the night of October 7-8, 1914).—For the understanding of this dream certain preliminary explanations are necessary. I possess four dogs, three being shepherd dogs with short hair, while the fourth is a white fox terrier with a few black spots. Several years ago I had a remarkably intelligent and devoted black poodle, called Nina, of which I was particularly fond. I was obliged to kill her because she had become blind and deaf. I have never had a short-haired yellow dog in my possession and none of the dogs with which I am well acquainted is like this, but a few days before a companion had pointed out to me a dog of almost exactly such an appearance. I must add, furthermore, that one of my shepherd dogs was afflicted with a tape worm and that a potion had been made ready to be administered to him the next day.

In my dream I thought that this draught of medicine had just been administered and that the animal which had swallowed it showed all the signs of a severe case of poisoning. It dragged itself painfully along, fell panting for breath, and seemed to be a prey to terrible suffering. It looked at me with supplicating eyes as if asking for relief. I was very deeply affected; I picked it up and tried to comfort it with words and caresses but felt that I was powerless to relieve it and had tears in my eyes. What made my pain so keen was that this animal seemed to be my dear little Nina. And yet the said Nina, who was actually a black poodle, in my dream appeared to be a much larger dog with short yellow hair and a long heavy body and short legs. . . . But I was not disturbed by this difference of appearance, which did not prevent me from thinking that the dog was my little Nina.

[1] *Revue philos.*, 1898.

[2] Jour. de psychol., norm. pathol., 1908, p. 358.

The Action of Ultra-Violet Rays on Sugar-Cane, Pineapple and Banana in Hawaii

By T. Tsuji

THE author made a prolonged study of the action of ultra-violet rays on plant physiology. In the paper under review he describes his recent investigations, which show perfectly clearly the connection between the action of these rays and the formation of carbohydrates, acids, and other compounds in sugar-cane, pineapple, banana, and other tropical plants.

Sugar-cane.—Perfectly normal sugar-canes were grown in the dark at a temperature of 22° C.; they grew but became pale. Thirty days later they were divided into two lots, one of which was exposed to direct sunlight, the other to ultra-violet rays from a quartz mercury vapor lamp. The etiolated leaves subjected to the action of ultra-violet rays turned a deep green after *two and a half hours*, whereas those exposed simply to sunlight kept their yellow color.

In another experiment three lots of sugar-cane were planted. One was covered with colored glass (to intercept 50 per cent. of the ultra-violet rays of the sunlight), the second was exposed normally to sunlight, and the third to the combined action of the sunlight and that of the mercury vapor lamp. These three lots received equal amounts of fertilizer. After several months the second lot was found to contain 30 per cent. more sugar than the first, and the third lot 8 per cent. more than the second. The increase in the weight of the sugar of each lot respectively in a given time points to the possibility of reducing the twenty months normally required for each sugar harvest to less than one year by the use of ultra-violet rays.

Pineapple and Banana.—Pineapples exposed to the action of ultra-violet rays ripen more rapidly than those exposed to sunlight only. Pineapples were subjected to the action of ultra-violet rays for forty minutes each morning; the fruit was riper, more juicy, and larger than that exposed to sunlight only. The same favorable action was observed on the banana. Banana leaves and stalks which had been cut and placed in water kept their original freshness even after two weeks when they had previously been subjected to the action of ultra-violet rays, whereas other untreated material was faded completely after six or seven days. The author sees in this a means of preventing the deterioration of exported bananas, but lays stress on the care necessary in the treatment as the distance, duration, and intensity have to be very carefully regulated.

Practical Sources of Ultra-violet Rays.—The ultra-violet rays of sunlight are quickly absorbed by the atmospheric gases, and only a small proportion of them reaches the surface of the earth. The use of mercury lamps is too expensive for practical application. The author, therefore, has attempted to devise more economical methods. In his latest system the ultra-violet rays are derived from small carbon rods impregnated with sodium tungstate, uranium nitrate, ammonium molybdate, and titanous chloride.—*Louisiana Planter and Sugar Manufacturer.*

Two-Cycle Paraffin Oil Engine

IN accordance with the requirements of the Government Department by which it was ordered, a 50-h.p., 2-cycle internal combustion engine made at Manchester by the Record Engineering Company was recently subjected to an endurance test of five days. During that time, says the *Times Engineering Supplement*, it ran continuously night and day at full load under paraffin oil, without attention or adjustment of any kind beyond the usual filling up of the fuel tanks and the supply of lubricating oil. None of the plugs was changed, and when the engine, which is of V type, with 4 cylinders and 2 cranks, giving 4 impulses per revolution, was dismantled at the end of the test, it is stated that no appreciable signs of wear were visible and that the cylinders were practically free from deposit. In the design adopted by the company, the two-to-one gears with the camshafts, cams, tappets, and poppets found in the ordinary 4-cycle engine, are eliminated and are replaced by a simple piston valve generally for each pair of cylinders worked by an eccentric on the main shaft. As a valve merely controls the distribution of the gaseous fuel to the pump cylinders it is not subject to a pressure exceeding a few pounds per sq. in. nor to the high temperatures of the working cylinders. The crank case is used only as a reservoir for lubricating oil, and not for handling the fuel mixture, so that the deposition of carbon and soot on the bearings is avoided, as also is the mixture of fuel oil with the lubricating oil.—*Jour. Ind. and Eng. Chem.*

Dressing beef carcasses under Government meat inspection

Saving Our Cattle

Government Cattle and Meat Inspection Service

THE Bureau of Animal Industry of the U. S. Department of Agriculture carries on numerous lines of work designed to protect the health of the country by preventing diseases among our cattle and by inspecting their meats when killed for food. Our cover illustration shows an effective method for preventing diseases among the cattle by compelling them to dip themselves in a vat of disinfectant which kills the disease-carrying insects often infesting both domestic and imported cattle. To catch disease at its source, if possible, this bureau also maintains a system of inspection and quarantine of imported animals to prevent the introduction of diseases from other countries, and returns good for evil by carefully inspecting animals intended for export from our confines.

The accompanying illustrations show government inspectors at their work in the great beef-packing establishments of the country. After undergoing the careful scrutiny of the general inspectors as shown in the large view at the top of this page, many pieces are held up for more careful inspection and sent to the "retaining room." The work of this room is shown by the cuts opposite. Meat that finally passes inspection bears the Government stamp in purple ink.

This bureau also studies the breeding and feeding of farm animals such as cattle, horses, hogs, sheep, and goats, as well as poultry, and gives information to aid people in raising live stock and poultry and in the production of eggs. It promotes the formation of clubs of boys and girls to raise pigs and chickens. It gives information about dairy farming, the care and improvement of dairy cattle, and the production and care of milk, butter, and cheese. It gives information and furnishes plans for the building of barns, silos, milk houses, etc. It also studies diseases of animals, and gives information and advice as to the nature of such diseases and how to prevent and treat them. It has undertaken systematically to eradicate some of the diseases. Publications prepared by experts and giving information on these various subjects will be sent without charge on application to the Bureau of Animal Husbandry, Department of Agriculture, Washington, D. C.

Sea Lions and the Fishery Industries*

By C. H. Townsend

AN important report on The Sea Lion Question in British Columbia has recently been made by a commission appointed by the Biological Board of Canada. The commission was charged with an inquiry respecting the effect of the bounty offered by the Dominion Government, with a view to reducing the numbers of sea lions in British Columbia, where there are important salmon-canning and other fishery industries.

The bounty was offered at the instigation of fishermen, market men and cannery men, on the claim that sea lions were enormously destructive to food fishes.

The work of the commission, or certain members of it, extended over several seasons. It included not merely inquiries relative to the bounty, but investigations covering the breeding places, numbers, food habits and utility of sea lions, together with hearings of complaints based upon their alleged destructiveness.

The commission, headed by Dr. Charles F. Newcombe of Victoria, performed its arduous field work with faithfulness. The conclusions and recommendations of the report are free from considerations of expediency.

The report covers the years 1915-16 and is an important contribution to the ever-recurring subject of seals and sea lions in their relation to the commercial fisheries.

These carnivorous animals abound along the coasts of many countries and have always been condemned by those who live by exploiting the fisheries. It is a remarkable fact that their food habits under natural conditions have not yet been studied to the extent necessary to the determination of their economic status. It is not many years since a vigorous attack against sea lions was made by fishing interests on the Pacific Coast of the United States. Many of them were killed before the extensive slaughter proposed by fishermen was checked. The rather limited investigations which were made at the time by federal agents served to show that most of the charges made by fishermen could not be proved. But we are not yet in possession of such facts regarding the food habits of the sea lion, as have been brought out in the case of the fur seal, which has been studied intensively. Until this has been done, the sea lion question cannot be determined on a basis of fact.

The inquiries made in British Columbia have thrown light on the subject, but what constitutes the *principal* food of the sea lion remains to be discovered. What the animal may eat when it wanders into the vicinity of extensive fishing operations, or what damage to fishing apparatus might be attributed to it, cannot safely be made the excuse for wholesale extermination.

It has been definitely ascertained that

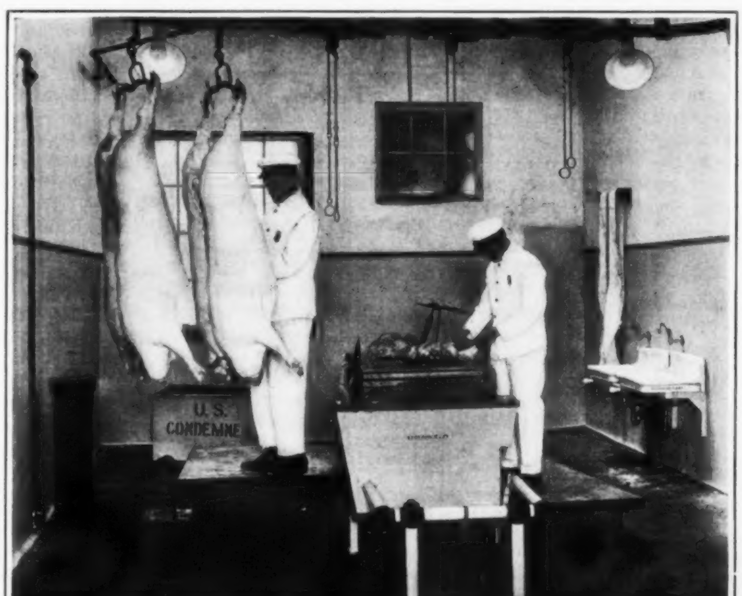
*From Zoological Society Bulletin, New York.

Carcasses that have been held up on first regular inspection are sent to the "retaining room" where they are carefully re-examined by special inspectors

the principal food of the fur seal is *not fish*. The same may be true with regard to the sea lion, but it will be more difficult to determine. The stomachs of large numbers of fur seals killed in the open ocean while feeding, were examined on the decks of sealing vessels and the results were conclusive. In the case of sea lions, examinations have been made of animals shot at their breeding places, where advanced digestion left few traces of food.

From the reports at hand from British Columbia, it appears that the bounty of $2 was paid on 4,074 sea lions. It is stated that not more than 50 per cent. of those killed could be secured, and "at a conservative estimate there must have been 8,000 killed," while the numbers killed elsewhere "would add materially to this number." The number of sea lions in that region was estimated in 1913 by Dr. Newcombe, Chairman of the Commission, at 11,000. In the report for 1916, it is stated, "while in round numbers 10,000 fairly well represents those seen on the rocks at the rookeries, there is a large number besides these, possibly even as great a number or greater, scattered over a wide area along the whole coast." The estimate of 10,000 does not include the 8,000 believed to have been killed previously.

The commission reports that there was little evidence of serious damage in 1916. "The sea lion is undoubtedly to blame for some torn nets and mutilated fish, but that he alone is to blame is open to question. Nets are commonly torn at other fish centers where the men scarcely know what a sea lion looks like. Valuable observations were made on the stomach contents of sea lions killed. Since it has been shown that fish not used for food as well as squid and devil fish are eaten, he cannot at all times be the epicure that some people would have us believe. Although he requires animal food, it is probable that he will take any kind available in quantity to satisfy his hunger. It is even possible that in helping to keep down other injurious species he does more good than harm to the fishing industry, provided he can be kept away from the nets or other fishing gear. If the disappearance of the dogfish is in any sense due to the presence of the sea lion, the sooner the matter is investigated the better. No other species is so much a pest as dogfish."



Special inspection room. The traveling table passes through a disinfecting tank as it is pushed along from time to time

In connection with the question as to the amount of food required by an adult sea lion, it might be well to mention that a California sea lion fourteen years old, which has lived in the New York Aquarium for eleven years and which weighed in 1917, 610 pounds, eats about sixteen pounds of fish a day. It would eat more, but this amount has been found sufficient to keep it in good condition. An eight-foot porpoise in captivity requires much heavier feeding.

Careful consideration is given to the commercial uses to which sea lion carcasses might be put. The weight of a twelve-foot sea lion was ascertained to be 2,240 pounds. The skin and fat are of recognized value, and the meat might also be made use of. There would certainly be fewer objections to the killing of sea lions if the carcasses were utilized. "It will be seen that in paying a bounty of $2 for each muzzle of a slain sea lion, and disregarding the hide and carcass, there is lost an opportunity to encourage the prevention of fishing depredations and at the same time, by means of a business organization centered in the government officials, make the sea lion, through its hide and carcass, pay the bounty and more."

Here we seem to be arriving at a possible solution of the problem. If the latent resources in the herds of sea lions which appear to some undetermined extent to be injurious to the salmon fishery, can be developed, the whole situation will change rapidly. When the sea lion itself becomes the basis of a fishery, in which the leather, oil and guano trades are interested, its conservation will be considered for commercial reasons. At present seal oil and leather are derived chiefly from the hair seals of the North Atlantic region. The sea lion of the North Pacific is available for legitimate exploitation.

"While the commissioners recommend that sea lions should be driven away or greatly reduced in numbers where it is evident that they are doing appreciable damage, they are not satisfied that there is any necessity for decreasing the numbers at other rookeries, except after some organized plan by which the pups could be free from injury, as in the case mentioned off the Oregon coast, in order that the industrial value of the sea-lions should be conserved, and more particularly in view of the possible friendly offices of the sea-lion that suggest further inquiry. Even in the case where it is considered necessary to diminish the number of sea-lions materially, the monetary value of the hide and carcass should be taken into consideration in any plan adopted."

Commercial fishermen in general have not distinguished themselves for broadmindedness. A fight to save the pelican has just been won in the Legislature of Florida, fishermen having introduced bills to permit the killing of pelicans, gulls and other birds which they describe as "terrifically destructive to food fishes." A bill introduced in the New Jersey Legislature to permit the killing of gulls was barely defeated.

The conservator of wild life has little chance to sit with folded hands. The tendency to destroy wild creatures not immediately serviceable to man always exists.

We know little of the food habits of sea lions and less of salmon after they enter the sea. Perhaps the salmon has an enemy in some form of marine life which is held in check by the sea lion. Such relationships are well known to science. The Pacific salmon and sea lions have dwelt closely together for ages, and were once infinitely more numerous, and it might not be well to divorce them.

If by some magic the sea lions could be wiped out of existence, the commercial fish catchers would doubtless be reckless enough to do it. They would be incapable of appreciating injuries that might result from disturbance of Nature's balance. Naturalists are broader minded.

The investigations made in British Columbia show that the killing of sea lions prior to 1916 on the rookeries adjacent to the Rivers Inlet region, served to keep them away that year. The manager of the canneries located there admitted that it was not necessary to kill sea lions, but that it would suffice merely to drive them away from that neighborhood. The commission very properly declines to favor any plan looking toward extermination, it having been shown that sea lions can be frightened away from localities where they do some damage. This they suggest could best be accomplished through the Federal Department of Fisheries, and add that "Indiscriminate and promiscuous killing should not be tolerated."

The species under consideration is Steller's sea lion (*Eumetopias stelleri*), which is found from California to Bering Sea and the Asiatic Coast. It is the largest of all sea lions. The writer killed a specimen on the Alaska Peninsula nearly thirteen feet in length.

It probably attains a weight of more than 1,400 pounds. Although as yet of little commercial interest, it has always been of great importance to the Aleutian Islanders, who make use of its skin, oil and flesh. The huge skin is the covering of their boats, the intestines split and sewed together are made into excellent rainproof garments, while the stomach is used for the storage of oil. On the Pribilof and the Commander Islands the supply of sea lions is carefully conserved, their skins being used in the construction of the great lighters or "bidarrahs" used in the loading and unloading of ships. A photograph of this efficient native craft is presented in this bulletin.

We cannot believe that the civilized world, having hitherto made little use of this large and abundant animal, can afford to destroy it for comparatively trivial reasons. While its numbers run into thousands, the figures count for little when compared with the millions that would have to be used in numbering the salmon.

The world is now, as never before, considering its supplies of food and oil and leather. The sea lion constitutes one of the resources of the sea. It must not be destroyed because its presence irritates salmon fishermen. Although formerly more numerous than at present, it produced no known effect on the stupendous runs of salmon that crowded the Pacific salmon rivers before wholesale and often unregulated commercial fishing decimated them.

Refractory Materials and the Glass Industry

The maximum temperature reached in the glass industry is 1,400° C., except in certain tank furnaces which are worked at a higher temperature to secure high output. In addition to the corrosive effect of the molten glass on the pots or tanks, the bricks in the furnace have to withstand the action of mechanically carried dust and of volatilised matter. Most of the refractory materials used in the glass industry are composed of fireclay or silica, or mixtures of these. When finely ground silica is added to finely ground alumina the melting point is steadily reduced from cone 42 to cone 29 (1,650° C.) for a mixture of 8 mols. SiO_2 to 1 mol. Al_2O_3, which is the same ratio as that in a very good and widely used brick. The anomaly is due to the material in the bricks being coarse-grained, so that the interaction between the silica and alumina is not so complete as in finely ground material. In mixtures of equal weights of fine fireclay and silica fragments of different selected sizes, heated under laboratory conditions, the silica did not begin to act as a flux unless the fragments were less than 0.0025 in. diameter. Larger fragments act as a stiffening agent and increase refractoriness, but when exposed for a week in a works furnace at 1,500° C. all the silica fragments less than 0.025 in. diameter exercised a definite fluxing effect. On substituting pitch for fireclay (so as to eliminate the solvent action of the fireclay on the coarse silica), it was found that the addition of silica always had a stiffening action, the most marked effect being with fine material which had passed through a 100-mesh sieve. Hence, the greater stiffening effect of the coarse fragments in silica-fireclay mixtures is due to their greater resistance to solvent action by the fireclay. There is an upper limit to the size of silica fragments which is permissible in bricks which depends upon the mechanical strength of the fragments and the local expansion of the silica. The proportion of clay which can be used in a mixture is limited by its shrinkage when the bricks are in use. Excessive shrinkage causes wide cracks into which liquids and vapors may penetrate and cause corrosion. Excessive expansion causes distortion and "crushing." If an alkaline vapor attacks a clay surface in such a manner as to form a molten silicate immediately, the latter soon closes the pores and the subsequent fluxing action is low. If the attack occurs at a lower temperature than that at which much fusion can occur, the vapor penetrates the brick or block and a complicated action of a destructive character may occur (see this J., 1910, 69, 250, 335, 399, 608, 799, 1091). If the temperature is afterwards increased the vitrified mass produced is liable to disintegrate.—*Jour. Soc. Chem. Ind.*

Iron as a Source of Color in Optical Glass

An optical glass melted in an electric furnace was free from color while the same batch when melted in a gas-fired furnace was distinctly green. The color was traced to the presence of iron in the gases constituting the furnace atmosphere. A sample of glass withdrawn previous to stirring was much less colored than the finished glass. After replacing the iron gas-burners by others made from clay and coating the interior walls of the furnace with kaolin, a distinct reduction in the color of the glass was obtained. The kaolin on the walls gradually acquired a red color due to absorption of iron either from the bricks or from the furnace atmosphere. It is desirable to use iron-free bricks for lining the furnaces, and any metallic iron used in the interior of the furnace should be water-cooled to prevent volatilisation of the metal.—*Jour. Soc. Chem. Ind.*

The Present Status of Nitrogen Fixation*

The Several Processes Contrasted on the Basis of Their Showing to Date

By Lieut.-Col. Alfred H. White, Ordnance Dept., U. S. Army

Fixed nitrogen in some form is an essential constituent of the food of all the higher animal and vegetable organisms. Fixed nitrogen in the form of potassium and sodium nitrates has been of prime importance in warfare since gunpowder came into general use. The ammonia resulting from the destructive distillation of coal has been recovered and used in the chemical industry for more than a century. *Free* nitrogen forms nearly eighty per cent. of the air we breathe, but in the free form it can be utilized neither by the bodily mechanism nor in explosives or fertilizers. The chemist has known for many years how to convert this inert gas into other compounds in his laboratory, but it is only within the last twenty years that the fixation of nitrogen has been recognized as an industrial as well as a scientific problem, and only within the last five years that its importance has become generally recognized.

Sir William Crookes, in 1898, called attention to the diminishing supply of Chilean nitrate, and the need of replacing it with a synthetic product if the world was not to be confronted with possible starvation as a result of shortage of nitrogen fertilizers. But although this stimulated interest and may almost serve as a date for the commencement of industrial research on nitrogen fixation, it was ultimately war and not peace which caused the rapid development of the processes for fixation of atmospheric nitrogen. One of the proofs of Germany's cold-blooded calculation is found in the subsidized development of the nitrogen fixation industry. The sodium nitrate vitally necessary for explosives was found only in Chile, and its supply would almost certainly be cut off in a war with a first-class naval power. The German government did not declare war until it had the Haber, Ostwald, and cyanamide processes developed to the point where it knew it could become independent of Chilean supplies.

SUMMARY OF FIXATION PROCESSES.

It is the first step in nitrogen fixation which is the most difficult. The nitrogen molecule as it exists in the air is very inert and becomes active only at high temperatures or in the presence of some activating substance. The processes may be classified as follows:

I—The arc process for the direct combination of the nitrogen and oxygen of the air to form nitric oxide which subsequently by oxidation with air and combination with water forms nitric acid of approximately 35 per cent. concentration. There are required about 10.5 h.p.-years electrical energy per ton of nitrogen fixed as nitric acid per annum.

II—The cyanamide process, involving:

(1) The production of calcium carbide through reaction between lime and coke in an electric furnace.

(2) The interaction of calcium carbide and pure nitrogen at a red heat to form calcium cyanamide.

(3) The decomposition of cyanamide by steam under pressure, to form ammonia.

(4) The oxidation of ammonia with air and combination with water to form dilute nitric acid of approximately 50 per cent. concentration.

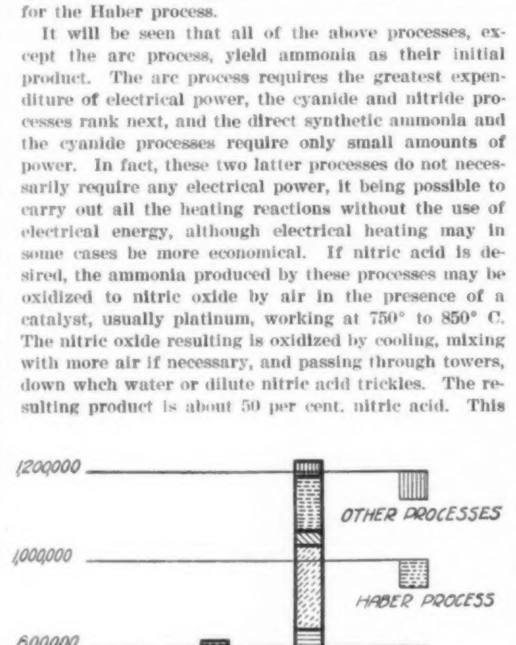
The power required by this process is approximately 2.5 h.p.-years per ton of nitrogen converted to nitric acid per annum.

III—Nitride processes. The best developed of these processes is that for making aluminum nitride from aluminum oxide, coke, and nitrogen heated to a temperature of perhaps 1800° C. in an electric furnace. This process has not been developed far enough to show its ultimate power requirements, but it is approximately in the same class as the cyanamide process. The aluminum nitride, after formation, may be decomposed with steam or dilute caustic solutions yielding ammonia and regenerating the alumina.

IV—The direct synthetic ammonia process, usually called the Haber process, wherein pure nitrogen and hydrogen are made to combine in the presence of a catalyst, at temperatures which in commercial work have usually approximated 500° to 600° C. and under a pressure of 100 atmospheres or higher. The ammonia made by this process is then oxidized with air and converted to nitric acid. Electrical energy is not necessary for this process and the total power requirements are only about 0.5 h.p.-year per ton of nitrogen fixed as nitric acid per annum.

V—The cyanide process, wherein a mixture of sodium carbonate and coke with iron in small quantities is heated in a stream of pure nitrogen to a temperature of approximately 1000° C., resulting in the formation of sodium cyanide. This furnace product may be decomposed with steam, yielding ammonia. Power requirements for this process are of the same order as for the Haber process.

It will be seen that all of the above processes, except the arc process, yield ammonia as their initial product. The arc process requires the greatest expenditure of electrical power, the cyanide and nitride processes rank next, and the direct synthetic ammonia and the cyanide processes require only small amounts of power. In fact, these two latter processes do not necessarily require any electrical power, it being possible to carry out all the heating reactions without the use of electrical energy, although electrical heating may in some cases be more economical. If nitric acid is desired, the ammonia produced by these processes may be oxidized to nitric oxide by air in the presence of a catalyst, usually platinum, working at 750° to 850° C. The nitric oxide resulting is oxidized by cooling, mixing with more air if necessary, and passing through towers, down which water or dilute nitric acid trickles. The resulting product is about 50 per cent. nitric acid. This



WORLD'S PRODUCTION OF FIXED INORGANIC NITROGEN EXPRESSED IN TONS NITROGEN

oxidation process requires very little external energy. It may be considered that the principal problem is to get atmospheric nitrogen into a combined form, and that the problem of converting the initial form of combined nitrogen into the final form is distinctly simpler and better elaborated.

THE WORLD'S SUPPLY OF FIXED NITROGEN.

The world can use almost any form of combined nitrogen, either directly or after conversion into a more desired form, so that the clearest way to obtain a view of the world's nitrogen supply is to reduce the figures for the various nitrogenous materials to a common basis of fixed nitrogen. The nitrogen in manure and other organic refuse, while important for agriculture, cannot be estimated with any accuracy. Our diagram shows the world's production of fixed inorganic nitrogen expressed in short tons of nitrogen for the years 1909, 1913 and 1917. No great accuracy can be claimed for these figures since some of them are mere estimates. It is believed, however, that the general situation is expressed correctly. The first outstanding impression is that of great growth in each period, but on closer analysis the striking fact is that the percentage increase from 1909 to 1913, when the world was at peace, is nearly as great as during the subsequent period when the world was at war. The increase is very closely fifty per cent. for each four-year period. The year 1913 shows an increase in production from every source. The year 1917 shows no increase from Chilean nitrate, in spite of the urgent demands of the Allies for greater supply. This was partly due to lack of ships. The greatest increase on the chart for the period 1909-13 is shown by the by-product coke ovens. In 1917 the increase was mainly due to the cyanamide and Haber processes, so that in this year the world's supply came almost equally from the three sources, Chilean nitrate, coke ovens, and synthetic, the cyanamide process being the most important in the latter group, with the Haber second.

In an attempt to distribute the world's production of fixed nitrogen by countries and processes only approximate accuracy can be attained, but certain important factors stand out clearly. In 1909 and 1913 Germany received nearly one-third of all Chile's nitrate. After the war broke out, she received none. If the war had continued, it is probable that the year 1918 would have seen the Chilean output increased nearly 25 per cent. over 1917. This probably represents nearly the maximum output, and it is believed that 500,000 tons of nitrogen as nitrate may be fairly taken as the most that can be expected from Chile.

The figures for ammonia from by-product coke ovens show a steady increase for every country, so that the coke ovens became the largest factor in the world's nitrogen production in 1917. There is every probability that a further increase was registered in 1918. Ovens still under construction, especially in the United States, will afford facilities for further material increase in 1919. In the periods studied, Germany shows the largest absolute as well as the largest relative increase in production from coke ovens.

The cyanamide industry more than tripled in each period, and rose in 1917 to a production of more than half of the euivalent in Chilean nitrate. Facilities provided since 1917 make a further increase of twenty-five per cent. possible.

The arc process shows a growth, but in spite of the stimulus of high prices, it has not attained prominence and remains centralized in Norway and Sweden, where water power is cheap.

The phenomenal growth of the Haber process is confined to Germany. The 8,000 tons production in 1913 represented success on a manufacturing scale and gave the German Government assurance that it could go to war, confident that neither foreign navies nor expensive electrical power could keep her armies from an adequate supply of the material most necessary for explosives.

RELATIVE TECHNICAL DEVELOPMENT OF FIXATION PROCESSES.

The two processes first commercially established were the arc process and the cyanamide process. Both have had a commercial development of approximately thirteen years in the hands of skilled chemists, chemical engineers, and electrical engineers in countries with high industrial development. There has, moreover, been mutual exchange of information between various groups of plants, both national and international, and the industry has become relatively stabilized along lines which represent the most advantageous process which the combined experts of the various affiliated companies have devised. Improvements will still undoubtedly be made, but the processes are relatively highly developed.

Experts in the arc process state that a commercial proposition to be attractive must have continuous electrical power in large units at not more than $12.00 per horse-power-year. Others state that power must be as low as $8.00 per horse-power-year. It gives as its sole primary product dilute nitric acid, or an alkaline nitrate or nitrite. There are attractive theoretical possibilities for increasing the efficiency of the arc process, but none have so far as we are aware, been developed far enough to hold out the hope that the arc process can ever be successfully operated except where large blocks of cheap electrical power are available. Even the stress of war conditions has failed to bring about the establishment of really large plants anywhere but in Norway and Sweden, and the total output by this process only amounts to about three per cent. of the world's total.

The cyanamide process has been studied since 1898 and has grown until in 1917 it furnished approximately one-sixth of the world's total fixed nitrogen. It requires large amounts of electrical power, but only one-fourth as much as the arc process. It also requires as raw materials large amounts of pure limestone and coke. It yields calcium carbide as an intermediate and cyanamide as its primary product, with ammonia, nitric acid, or ammonum nitrate as subsequent products obtained by relatively efficient processes. It stands as an ex-

*Address delivered at the Chicago meeting of the Am. Inst. of Chem. Engs. Reprinted with elimination of that part pertaining to war-time engineering measures adopted by the U. S. Government, from *Jour. Ind. & Eng. Chem.*, where it appeared by permission of the Chief of Ordnance.

ample of a highly developed chemical industry dependent for commercial success upon relatively cheap electrical power in large units. The war has seen one variant of this process receive an extensive test in this country on a semi-industrial scale, with such favorable results that a commercial plant is now being erected.

While many metals yield nitride when heated in nitrogen, the manufacture of aluminum nitride has received most attention because of the possible importance of the alumina obtained as a by-product, for the aluminum industry. It requires large amounts of electrical power and a rather specific raw material, bauxite. The commercial developments of the past have not been successful, and although more is hoped from the two large semi-commercial installations now being tested in this country, it must still be regarded as a rather unproven process.

The cyanide process does not require electrical power and uses as its raw materials sodium carbonate, coke, iron, and pure nitrogen. Of the raw materials the iron is always recoverable and if the cyanide is converted into ammonia under proper conditions, the sodium carbonate is also recoverable, leaving as the only raw materials actually expended nitrogen and coke in the cyanizing reaction, and steam in the ammonia reaction, together with the coal required to furnish the heat. The initial product is cyanide which may be purified and marketed as such or converted into ammonia with a possibility of sodium formate as a by-product. The development has been largely in the United States and since the war broke out. The commercial possibilities of this process have not yet been established. The present developments have tended toward an externally heated steel or nichrome retort as the most suitable container for the cyanizing reaction which requires a temperature of 1,000° to 1,100° C. The retort is necessarily small and the reaction is rather slow. The process attracted the Government during the war because it was certain nitrogen could be fixed without the use of large amounts of electrical energy, which were then almost unobtainable. At present the process involves high capital, labor, and repair costs. The process must not, however, be condemned in its present immature form.

The direct synthesis of ammonia from nitrogen and hydrogen was first developed both from the theoretical and practical side in Germany, and the name most frequently associated with it is that of Haber. The combination of nitrogen and hydrogen according to the reaction

$$3H_2 + N_2 \rightleftarrows 2NH_3$$

is favored by high pressure and relatively low temperature. Some of the equilibrium values are given in the following table:

Temp.	Per cent NH_3 in equilibrium at pressures (in atmospheres) of			
°C.	1	30	100	200
700	2.18	31.8	52.1	62.8
500	0.129	3.62	10.4	17.6
300	0.0223	0.66	2.14	4.11

The rate of reaction between the gases is altogether too slow to be commercial unless accelerated by a catalyst. Our knowledge of catalysis is still very vague, and catalysts are discovered only by tedious experiments largely empiric in their nature. Furthermore, they are extraordinarily susceptible to poisons.

While therefore the reaction between nitrogen and hydrogen is extremely simple to write, it is extremely difficult to carry out economically. The successful solution of the problem involves many problems but they may be divided into four groups: preparation of pure nitrogen, preparation of pure hydrogen, preparation of catalyst, and construction of plant.

It is unfortunate that the term "fixation of nitrogen" fixes attention so strongly on nitrogen that the lay mind gains the impression that one of the chief difficulties to be overcome is the preparation of the nitrogen. The arc process starts with air but all the other processes require or at least work distinctly better if supplied with nitrogen substantially dry and free from oxygen, carbon dioxide, and carbon monoxide. Argon, helium and other rare gases of the atmosphere interfere only as they dilute the nitrogen slightly. The supply of pure nitrogen is important, but fortunately the liquid air process furnishes it so cheaply and reliably that the problem may be considered as solved. A nitrogen column as delivered to the United States nitrate plants has an hourly capacity of 20,000 cubic feet of dry nitrogen, with less than 0.1 per cent. oxygen for an expenditure of 180 horse-power-hours. Power is by far the most expensive item, for air is free, only a small amount of caustic is needed for purification of the entering air, and the labor charge is small. The operation is so reliable and the cost so small that efforts to recover waste nitrogen from industrial sources are hardly worth while where a really large installation is being considered.

Pure hydrogen is needed only for the direct synthetic ammonia process. It forms 17.6 per cent. of the theoretical gas mixture by weight, but 75 per cent. by volume. Hydrogen is formed as a by-product in the electrolytic manufacture of chlorine, but the expense of collecting it and purifying it is considerable. Hydrogen and oxygen are obtained by electrolysis of caustic solutions, but it is difficult to find a location where both gases can be used to advantage. It is also made by the action of steam on red-hot iron and by the water-gas reaction wherein steam reacting with coke produces approximately equal volumes of carbon monoxide and hydrogen. By further reaction with steam in the presence of a catalyst, as shown by the following equation,

$$CO + H_2O \rightleftarrows CO_2 + H_2,$$

most of the carbon monoxide may be removed with the formation of an equal volume of hydrogen, but a long and elaborate purification process must be followed to bring the gas to a pure and dry state. The refinement of purity necessary will vary with the different catalysts, but the impurities must certainly be measured only in hundredths of a per cent., if not thousandths. Further research work on the purification of hydrogen is desirable.

FUTURE OF NITROGEN FIXATION PROCCESSES.

The future of the nitrogen fixation industry can be forecast only in the most general manner. It depends upon two factors, the demand for fixed nitrogen and its price. These two factors are in part independent and in part linked together, for a lowered price is certain to cause a greater demand. The principal demand of the last few years has been for munitions, and the demand was an insistent one which had to be met regardless of price. The great normal demand for fertilizers has been restricted to a minimum. The largest demand for fixed nitrogen in the future will probably be for fertilizers, and the use of fertilizers will be very largely a matter of price. The diagram shows an increase of roughly fifty per cent. in output for fixed nitrogen for each four-year period. It is not probable that 1921 will show such a proportionate increase although if all the resources of Chile and all of the facilities in the way of coke ovens now under construction, and fixation plants should be utilized, the year 1920 might well see a possible production of 25 per cent. more than 1917. What will be the cost of production? The cheapest source of fixed inorganic nitrogen will undoubtedly be the ammonia from by-product coke ovens because it is a by-product and the cost of collecting and putting it into marketable form is small. The coke ovens of the world can now produce more fixed nitrogen than the world used from all sources ten years ago. It will be a powerful factor tending towards low prices. It is probable that Chilean nitrate could, if necessary, be sold at lower prices than in former years. The fixation processes will therefore have to be prepared to meet possible low prices if they are to be ranked as anything more than emergency reliances.

The cost of nitrogen in the staple raw materials, sodium nitrate and ammonium sulfate varied from $12 to $16 per hundred pounds in the years 1900-1915. It is manifest that a process which is to produce a large proportion of the world's fixed nitrogen must be able to compete with these staple materials. Smaller factories may produce specialized products such as sodium nitrite and anhydrous ammonia for which there is a demand, large in itself, but small in proportion to the world's total demand.

The necessity and the possibility of independence of Chilean nitrate as a material for munitions has been proved in the past four years. The question as to whether the fixation processes can compete with Chilean nitrate and coke oven ammonia in times of peace, and for the cheapest commercial nitrogenous product—fertilizer—cannot yet be answered.

The cyanamide and arc processes both labor under the handicap of the requirement of large amounts of electrical power. The nitride process has a somewhat similar handicap but possesses a possible advantage in the recovery of alumina as a by-product. The cyanide process labors at present under the disadvantage of small manufacturing units but has the advantage of low-power requirements and the possible recovery of formates as by-products. The direct synthetic ammonia process presents great engineering and chemical difficulties, but has great possibilities of future development. As will be seen from the table earlier in this paper, if an inventor could find a catalyst active at 300° C., he would have the theoretical possibility of increasing the conversion by one passage through the apparatus at 100 atmospheres pressure to fivefold the conversion at 500° C. Or with such a catalyst, he could work at 30 atmospheres pressure and 300° temperature, eliminating thereby many of the serious engineering difficulties and still obtaining a conversion far better than anything now commercially known to us. There is no theoretical reason why such a catalyst might not be made, and its discovery would offer the possibility of cheaper fixed nitrogen than anything heretofore known.

The Anthropology of Poland

The nationalities of Europe have been much under discussion during the last four years; indeed, apart from the progress of the actual military operations, probably no other subject has been so prominently before the public. Yet a surprisingly small proportion of what has been written has been valuable or even accurate. A serious knowledge of European ethnography is still confined to a very narrow circle, and the ordinary journalist habitually makes the most grotesque errors. This is the more to be regretted because the subject, though much more complex than the average Englishman supposed before the war (he must now be utterly bewildered by the torrent of unfamiliar names), is not so difficult than an outline of the facts could not be made comprehensible in quite a brief explication. The chief complexities relate, of course, to Eastern and East-Central Europe. A most important and valuable contribution to this part of the subject has been published in the *Journal of the Royal Statistical Society*, vol. lxxxi. pt. 2, March, 1918, in the shape of a paper by Geoffrey Drage entitled "Pre-war Statistics of Poland and Lithuania." The article (which is nearly 100 pages in length) is partly of sociological and partly of ethnographical interest; but it is, of course, only the latter aspect with which we are here concerned. It appears that the total Polish population of the world is about 26,000,000, of whom 23,000,000 still live in Europe, nearly all (except half a million who have migrated to Western Germany) dwelling of course in the sundered territories of historic Poland. It is important to note, however, that the Poles constitute less than 40 per cent. of the population of historic Poland. The Poles in their day were an imperial race, and they imposed their rule upon millions of Russians. Thus certain provinces of historic Poland became part of Russia proper, not merely of "Russian Poland," and Russian they ought to remain. Minsk and Volhynia have only 10 per cent. of Poles, Mooghileff and Kieff have but 3 per cent. On the other hand, in the so-called Kingdom of Poland 75 per cent. of the population are Polish. The Poles are in a very large majority in Western Galicia. In Prussian Poland the Poles are a majority in Posen and Silesia, but not in the province of West Prussia. The paper also gives interesting and important data relating to the Lithuanians, Letts, White Russians, Ukrainians, and Jews. Mr. Drage says that the total Hebrew population of the world is slightly under 12,000,000, almost exactly half this number being Polish Jews. The Jews constitute about 15 per cent. of the population of the so-called Kingdom of Poland, and 10 per cent. of that of Galicia. Several maps are appended to the paper showing the distribution of the Poles.—*Science Progress.*

Rapid Estimation of Lead in Brass and Alloys

Rapid gravimetric and volumetric methods for the estimation of lead in brass and similar alloys are desribed by G. H. Hodgson, in *Chemical News*. *Gravimetric method.* Five grams of the alloy is dissolved in 25 c.c. of nitric acid (sp. gr. 1.4), the solution is diluted with 200 c.c. of water, and sufficient ammonia solution (20 c.c. of sp. gr. 0.880) added to precipitate all the copper. Sufficient 80% acetic acid is then added to produce a clear, slightly acid solution, which is treated with 10 c.c. of 3% potassium bichromate, shaken and allowed to stand for an hour. The precipitated lead chromate is collected on a paper pulp pad, washed to remove the copper, and treated on the filter with hot 30% sulphuric acid until entirely converted into sulphate. The sulphate is washed with water and dissolved by pouring about 40 c.c. of hot ammonium acetate solution containing acetic acid through the filter. The solution is raised to the boiling point, and treated with ammonium molybdate. The precipitate is collected on an ashless paper pad, washed with water containing a little ammonium acetate, ignited, and weighed as lead molybdate. The whole process may be completed in four hours. *Volumetric process.* The lead is precipitated as chromate as described above, the chromate precipitate is washed with water and warm dilute acetic acid (5%) until free from copper and excess potassium chromate, then dissolved by pouring cold hydrochloric acid (1 : 4) on the filter, and the pad is finally washed with water to collect all the chromic acid. The free chromic acid may then be estimated by titration with standard ferrous ammonium sulphate or by adding potassium iodide solution and titration of the liberated iodine by standard sodium thiosulphate solution.—*Jour. Soc. Chem. Ind.*

The Metallurgy of Copper

A Few of the Fundamentals Connected With Its Production and Use

By Thomas H. A. Eastdick

The outstanding characteristics of the remarkable metal copper are the ease with which it can be wrought and its resistance to decay. Copper and bronze articles have been found which have resisted decay and corrosion for thousands of years. It was, however, its deep rich red color, and the great variety of colored finishes which it can be made to assume, that caused it to be so generally used through all the ages.

At the present day approximately 80 per cent of the world's supply of copper is produced in the United States and Mexico, amounting to over 1,000,000 tons last year. Most of this copper is mined in two principal districts; these are the Great Lakes district where all of the so-called "Lake Copper" is produced, and the copper district of Montana, Idaho and Utah.

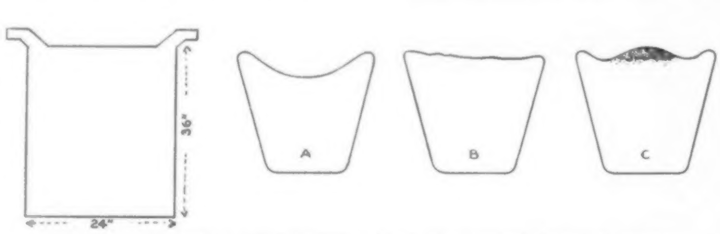
The western ores are smelted at the mines, the finished product of the smelters being "blister copper" which is an impure metal containing about 96 per cent. copper, small quantities of gold, silver, tellurium, arsenic, antimony and iron. This blister copper is poured into iron moulds to form anodes, which are usually of the form shown in Fig. 1. Blister copper anodes are the final product of the smelter and the raw material of the electrolytic refineries. With the exception of one at Great Falls, Mont., all the large electrolytic refineries are located on the Atlantic coast, particularly near New York. Blister copper is shipped east, usually in the form of anodes, to these refineries and there electrolytically refined and cast into ingots, wire-bars, cakes, etc.

The process of electrolytically refining copper consists of transferring the copper from the blister copper anode to a pure thin-sheet copper cathode in an electrolyte consisting of a dilute solution of copper sulphate and sulphuric acid, by means of a suitable electric current. This operation is carried out in large wooden tanks, about 16 feet long and 5 feet wide and deep, lined with asphalted felt. The anodes and cathodes are suspended on conducting rods running lengthwise on the tanks and the current is caused to pass from the anodes to the cathodes through the solution. The voltage required depends, of course, on the resistance offered by the solution and the copper electrodes, and the amperage is usually about 15 amperes per square foot of anode surface. One ampere will deposit approximately 1 ounce of copper per 24 hours.

A most important feature of the process of electrolytic refining of copper is the recovery of gold and silver. Providing conditions are right practically nothing is deposited on the cathode but copper, and the impurities in the blister copper anode either pass into solution or form a sludge which settles to the bottom of the tank. This sludge contains all the gold and silver present in the blister copper, along with the antimony, iron and tellurium, etc. The sludge amounts to approximately 3 per cent. of the total weight of the anodes refined and when dried and screened contains as high as 40 per cent. silver and 1 per cent. gold.

The cathodes, consisting now of pure copper, analyzing 99.95 per cent. copper, are charged into a reverberatory furnace of from 25 to 50 tons capacity, and melted, rabbled and "poled." This poling operation is very important and is really a de-oxidizing reaction. Copper forms two oxides, black copper oxide, CuO_2, and red copper oxide, Cu_2O. This red oxide of copper is soluble in molten copper and forms with it a definite alloy series, and small quantities of it present in the copper affect the physical properties to a very great extent. For many purposes absolutely pure copper containing no cuprous oxide is unsuitable, while on the other hand, an excess of cuprous oxide is equally undesirable. In order for the metal to have its maximum toughness it must contain a definite quantity of this cuprous oxide, and for this reason that "pitch" in copper at which point it has maximum toughness is known as "tough-pitch" copper.

The pitch is really the crown or the absence of it on top of the copper after solidifying. Fig. 2 shows the three principal stages of copper with respect to its oxygen content as shown by the top of the ingot or cake, etc. Fig. 2-A shows the appearance of an ingot when the copper contains an excess of oxygen in the form of cuprous oxide. It will be noticed that the ingot has shrunk considerably, forming a deep depression in the top of the ingot. Fig. 2-B shows the appearance of an ingot which contains just the right amount of cuprous oxide and in which the copper is at its maximum condition of toughness. Such a copper is known as "tough-pitch." Fig. 2-C shows the appearance of an ingot in which the copper contains no oxygen in the form of cuprous oxide. It will be noticed that the copper has apparently swelled on solidifying, thus raising a lump in the center of the ingot. Close examination of this lump reveals the fact that it is honeycombed with fine gas holes and looks somewhat like a miniature sponge.



Figs. 1 (left) and 2. The former shows the typical form of copper anode which goes to the refinery; the three drawings under Fig. 2 show characteristically under-poled, tough-pitch and over-poled copper ingots, respectively.

The de-oxidizing process as carried out in the refining furnaces, and which is known as the poling operation, is so called because it is carried out by stirring the molten copper with long poles of green wood. The copper when melted contains a fairly high percentage of cuprous oxide, and upon the introduction of the wood this cuprous oxide is reduced to metallic copper, with the liberation of the oxygen in the form of steam and carbon dioxide. When the pole is introduced into the copper violent decomposition occurs with the evolution of large quantities of gases of a reducing nature. The reduction of the cuprous oxide proceeds until no oxide is left in the copper and the metal starts dissolving the gases given off by the decomposition of the wood. This explains the peculiarities which we find in the ingot in the case of Fig. 2-C, which represents an ingot of over-poled copper; the metal has dissolved a considerable quantity of hydrogen given off by the wood, and upon freezing has liberated this gas, which has risen to the top of the ingot, thus raising a lump honeycombed with gas holes. Fig. 2-A represents an ingot of "under-poled" copper which contains an excess of the oxide which causes the metal to shrink excessively, thus forming a depression.

The Lake copper mentioned above occurs as native copper in the region of the Great Lakes, and very little treatment is necessary to recover the metal. The gangue associated with it is separated by crushing and jigging. The metallic copper is simply furnace refined, poled and poured into ingots in the same manner as cathode copper. Native copper sometimes occurs in the Lake region in quite large masses, occasionally ten to fifteen tons in weight of absolutely pure copper without any rock or gangue.

Originally practically all of the copper in this country came from the Lake region and, inasmuch as it was a very pure grade, was always looked upon as being the very best copper obtainable. This prejudice in favor of Lake copper was in existence long after the introduction of electrolytic copper, and in some quarters it exists today; in fact, prior to the outbreak of the war Lake copper commanded a higher price than electrolytic, although it is not as pure as electrolytic and has a much lower electrical conductivity. It is common to find many copper consumers specifying Lake copper in preference to electrolytic, without any substantial reason for this preference.

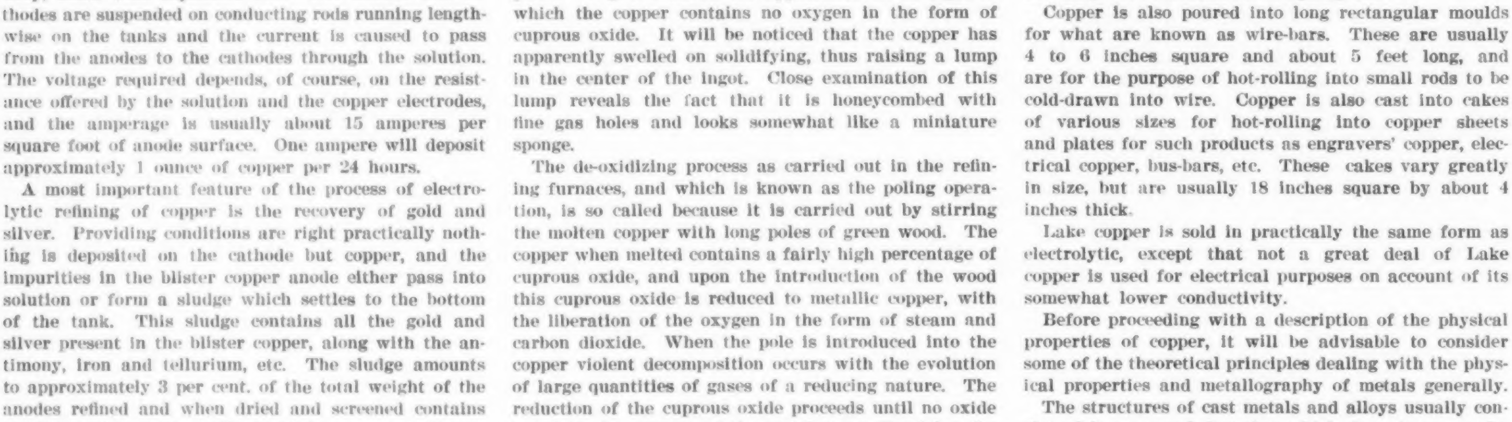
The copper after the poling operation is poured into a great variety of shapes and sizes for various purposes. Thus we have the ordinary ingot copper which is intended for remelting purposes, as in brass making, etc. In this case the copper is poured into ingot moulds which are about 9 inches to 12 inches long, 3 inches wide and 4 inches deep. The moulds also have what is called a "heel" which gives a deep gash in the ingot enabling it to be easily cut or broken for weighing out.

Copper is also poured into long rectangular moulds for what are known as wire-bars. These are usually 4 to 6 inches square and about 5 feet long, and are for the purpose of hot-rolling into small rods to be cold-drawn into wire. Copper is also cast into cakes of various sizes for hot-rolling into copper sheets and plates for such products as engravers' copper, electrical copper, bus-bars, etc. These cakes vary greatly in size, but are usually 18 inches square by about 4 inches thick.

Lake copper is sold in practically the same form as electrolytic, except that not a great deal of Lake copper is used for electrical purposes on account of its somewhat lower conductivity.

Before proceeding with a description of the physical properties of copper, it will be advisable to consider some of the theoretical principles dealing with the physical properties and metallography of metals generally.

The structures of cast metals and alloys usually consist of large rounded grains which do not, as a rule, resemble crystals. The sharp angular characteristics of crystalline formation are only obtained after the metal has been worked and annealed. Our first photograph shows the structure of ingot copper which illustrates this fact very noticeably. Eutectics, which are solidified saturated solutions of one metal in an-



The microstructure of copper. The first photomicrograph shows, with an enlargement of 75 diameters, the structure of cast copper ingots; the black dividing lines are the eutectics; their formation is shown in greater detail in the second picture, which is magnified 300 diameters. The third and fourth views show the copper of the first cut after cold working, which distorts the grain, and after annealing, which alters the crystal structure altogether. Both these views are magnified 75 diameters.

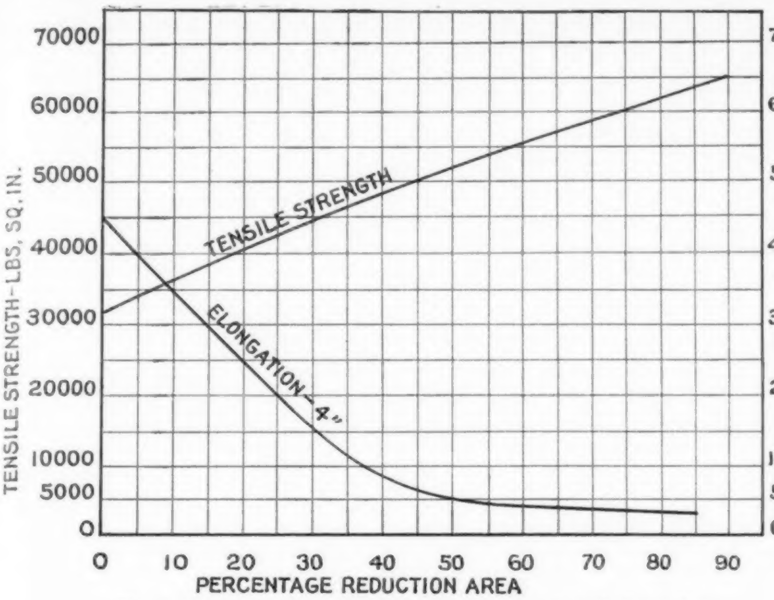


Fig. 3—The effect of rolling upon tensile strength and elongation under a given stress

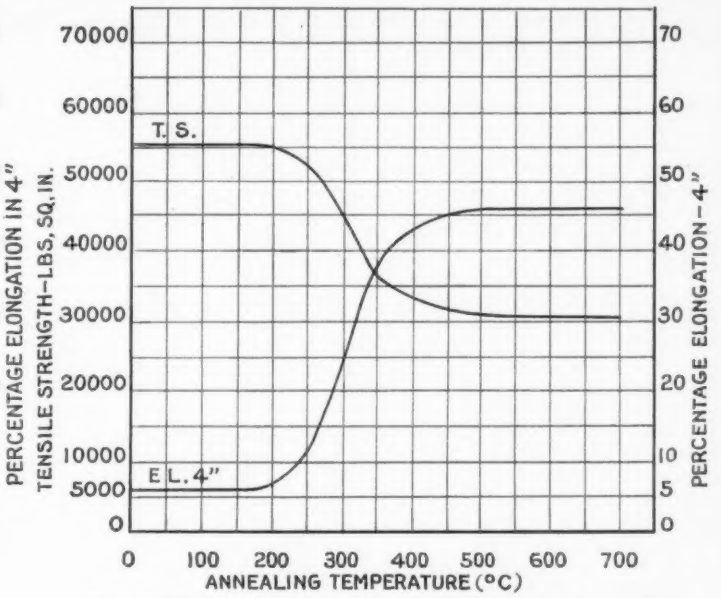


Fig. 4—Effects upon the same physical properties of annealing hard-rolled copper

other, owing to the fact that they are the final portion of an alloy to freeze on cooling from the liquid state, always form an interlacing network between the large grains of the pure constituent. Eutectics are characterized by a very fine banded structure, usually requiring quite high magnification to reveal the structure. As has been mentioned above, cuprous oxide and copper form a definite alloy series, the eutectic of which contains 3.4 per cent. cuprous oxide; the eutectic having a much lower melting point than the copper, is the last portion to freeze and therefore appears surrounding the grains of copper. The black network surrounding the grains of copper in the photograph is this eutectic. A second photograph shows the eutectic in greater detail, the picture having been taken at a much higher magnification.

If we take a metal having a cast structure and perform upon it cold work, such as hammering, rolling, drawing, etc., we find that the large primary grains have been distorted out of shape. If the work has been very severe the grains will become almost obliterated and the structure will become almost amorphous. The appearance of ingot copper after cold work has been performed upon it is shown in the third photograph. Upon annealing it we find that the original structure has completely disappeared and an entirely new crystalline structure has appeared, as the fourth photograph. It will be noticed that the crystals are sharply defined and show more of the characteristics of true crystals than the rounded grains of the original cast structure. Another picture shows the same sample very much over-annealed.

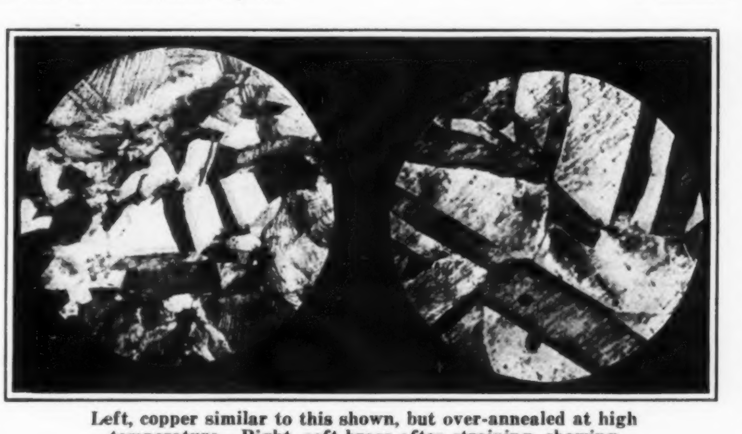
Microscopic examination affords a very useful method of checking up metal manufacturing processes, and in some cases it is almost indispensible. The structure obtained on a metal is greatly affected by slight variations in the various processes of manufacture, and microscopic examination of failures or defective material usually indicates the nature of the trouble and also a remedy.

All metals undergo some remarkable changes upon being cold-worked by any means whereby the metal is caused to flow while in the cold state. The most obvious change that takes place is the increase in maximum strength and elastic limit and the decrease in elongation, or, in other words, the metal becomes very much harder and correspondingly brittle.

At this point it seems advisable to consider definitions of some of the terms which are somewhat loosely applied in common practice. The word "hardness" as applied to metals is too ambiguous to be of service. As ordinarily applied it means the possession by a metal of a high tensile and compressive strength with little or no elongation. Theoretically, perfectly soft metal would have no elastic limit, with infinite extensibility; and conversely, the theoretically perfectly hard metal would have infinite elasticity with no permanent elongation.

The elastic limit of a metal may be defined as being the load at which the metal commences to flow. Bearing this consideration in mind, therefore, we find that with a very hard, brittle metal, the elastic limit and maximum tensile strength practically coincide, and conversely, with a very soft metal the elastic limit is very small in comparison with the maximum tensile strength.

Carrying the above definition of elastic limit a little further we may say that it is the load at which the crystals of a metal commence to slip with respect to each other. This slippage also taking place inside the individual crystal.



Left, copper similar to this shown, but over-annealed at high temperature. Right, soft brass after straining, showing slip bands. Both magnified 75 diameters

If we take a piece of soft metal and deform it in such a way as to exceed its elastic limit, and examine it under the microscope, we find that each crystal has on its surface a series of lines. These lines are parallel in the same crystal but show different orientation from crystal to crystal, as shown in the photograph of brass. These lines are known as slip-bands and are the result of the cleavage planes in each crystal slipping.

Figure 3 shows the curve obtained by plotting the results of physical tests obtained on specimens of copper rolled to various reductions in thickness, against the percentage reduction of area of the specimen, or in other words the degree of cold deformation which the metal has been subjected to by drawing. Examination of this characteristic curve shows that the soft annealed metal has a tensile strength of 32,000 pounds per square inch which increases upon drawing to approximately 65,000 pounds per square inch after 90 per cent. reduction in area without annealing. Conversely the elongation is reduced from 45 per cent. in 4 inch for the soft metal to 4 per cent. in 4 inch for the hard drawn metal.

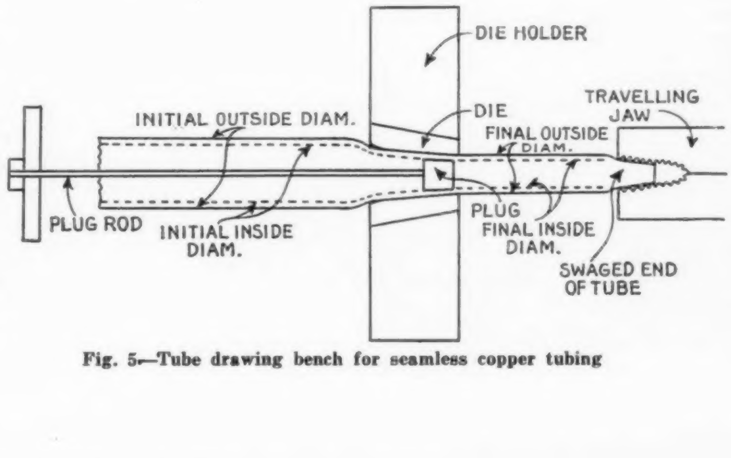


Fig. 5—Tube drawing bench for seamless copper tubing

The phenomenon of hardening up due to cold-working is common to all metals. Beilby's theory as to the cause of this phenomenon assumes the existence of an amorphous phase in metals. This phase is presumed to be a brittle vitreous substance similar to glass in its general properties. Taking an annealed crystal structure and performing cold-work upon it is supposed to cause slippage along crystal planes, with the resulting formation of the vitreous material; the more severe the strains set up, the greater the quantity of amorphous material that is formed. Theoretically this process can proceed until the metal consists entirely of the amorphous phase, and when this point is reached the material possesses a maximum hardness with no ductility, and no further work can be performed upon it without cracking.

Upon annealing a strained structure, that is, a metal containing amorphous material, the amorphous phase disappears with the formation of an entirely new set of crystals. Bearing these considerations in mind, therefore, we may consider the process of annealing metals in order to soften them as being a process of heating in order to impart sufficient mobility to the molecules of the metal to enable them to rescrystallize. The temperature at which the recrystallization takes place varies considerably for different metals. Naturally those having low melting points crystallize at a generally lower temperature, but for any given metal, the higher the state of strain under which the metal is, the lower the temperature of recrystallization. This is in accord with the principle governing all changes of state in matter whereby the nearer it is to an equilibrium, the more energy is required to actually bring it to the state of equilibrium.

Metal in the state of strain resulting from cold work is not in equilibrium, and the more cold work that has been performed upon it the further it is from being so, with the result that less energy in the form of heat is required to change its state.

Figure 4 shows the effect on the physical properties of hard rolled copper of annealing. The specimens had been reduced approximately 50 per cent. in thickness by rolling, and were then annealed at various temperatures and physical tests made. It is rather remarkable that copper in a state of strain should be affected

(*Continued on page* 335.)

Scientific Signalling and Safety at Sea*

Modern Efforts to Protect the Mariner from Fog and Other Perils

In the British Admiralty pilot and sailing directions still extant the sailor is informed that there is no help in a fog, save unreliable fog signals and the use of the lead. "Sound is conveyed in a very capricious way through the atmosphere. Apart from wind, large areas of silence have been found in different directions and at different distances from the signal station, in some instances even in close proximity to it. The mariner should not assume that, because he fails to hear the sound, he is out of hearing distance; that he is at great distance, because he hears the signal faintly; that he is near it, because he hears it plainly; that the signal has ceased sounding, because he does not hear it; and that the distance and the intensity of the sound on any occasion are a guide to him for any future occasion. The lead is generally the only safe guide in fogs." These words were quoted by Professor John Joly, F.R.S., of Trinity College, Dublin, in introducing his two Tyndall lectures on "Scientific Signalling and Safety at Sea," delivered at the Royal Institution on April 9 and 10. Much that Professor Joly advocated in these lectures, which we abstract, is still in the experimental stage. That it remains in that stage, in spite of scientific progress, is largely due to the war, and in general due to a justified conservatism of the sailor. When normal conditions have been restored, however, many promising suggestions will have to be thoroughly tested, and the antiquated navigation rules consequently revised. More is at present done for the comfort, than for the safety, of passengers at sea, and some of the means suggested for increasing safety depend upon devices already in use for the transmission of news.

Dealing first with recently introduced coastal signals, Professor Joly remarked that the Admiralty directions he had quoted were not intended, of course, to imply the worthlessness of aerial sound signals. But recent advance in science had supplied additional safeguards, in the first instance "synchronous signals." When we saw the flash of lightning, and heard the thunder two seconds later, we concluded that the storm was 2 × 1,100 feet away since sound was propagated at 1,100 feet per second. If the Dover express travelled at 40 miles per hour, it would reach London, 80 miles distant, in 2 hours. To a certain extent a man in London could follow the progress of the train, if a friend in Dover sent him a signal when the train left, and again at intervals of 15 minutes; whenever he heard the signal, he would know that the train was 10 miles nearer London. In this way the sailor could benefit from synchronous signals without the aid of a stop watch. If a lightship near shore discharged a gun and at the same moment gave a light flash; hearing the report 3½ seconds after seeing the flash, the sailor would know that he was somewhere on a circle of radius 3½ × 1,100 feet, and the flash would give him the hearing of the station. But the flash might be obscured by fog and rain, and the sound was difficult to pick up in stormy weather, while there were the "zones of silence" already mentioned. The sound waves seemed to arch over certain areas, and would thus travel on indirect, longer paths, conveying a wrong idea as to distance. Yet the simple aerial signal should not be condemned any more than lighthouses were. Automatic bell buoys, common on our coasts, were often combined with occulting lights. The bell rocked up and down with the motion of the water, and a horizontal vane beneath the bell oscillated and compressed, through a ratchet, a spring which was finally released and actuated the hammer. Even in the calmest weather three or more strokes might be given per minute, not at regular intervals, but fairly of the same intensity, and the number of strokes could be limited to, say, three per minute. When a light flashed up simultaneously with the stroke, and the flashes were spaced to follow one another at intervals corresponding to a sound-propagation of one cable (0.1 nautical mile) *i. e.*, at a little more than half second, then the sailor, counting the flashes between consecutive bell sounds, would see a second flash after the sound had travelled one cable, and a tenth flash, after the sound had travelled 9 cables and so on, and he could thus ascertain his distance from the buoy without the use of a stop watch. This was valuable for small craft not equipped with signalling appliances.

With the aid of radiotelegraphy and submarine signalling, these devices could be much perfected. As sound travelled in water at the rate of 4,800 feet per second, the submarine bell-stroke would lag behind the radio by 1-2 seconds for each nautical mile traversed, if the signals were simultaneous; and simultaneous air and water sounds would differ by 4.3 seconds per nautical mile traversed. The rate of propagation of sound through water had really been determined on these lines by Collodon and Sturm in 1826, in the Lake of Geneva—the bell stroke ignited some powder, and the sound was listened to in a trumpet immersed in the water. Divers were well aware of the startling audibility of sound under water. Experimenting years ago off the Dublin coast, on means of ascertaining the depth of the water under a moving vessel, Professor Joly had observed that the explosion of a small cartridge containing ½ ounce of gunpowder, fired at the bottom of the sea, was easily perceived a mile away in open boats (unprovided with any form of sound-receiver) as a blow striking the bottom of the boat.

The modern submarine bell now largely used, is made of bronze; it weighs 220 pounds, and has a period of 1,215 vibrations in water. The striking mechanism is contained in a cylindrical casing above the bell. The bell is suspended by a chain at a depth of about 18 feet, and the cylinder is fed with compressed air from a reservoir on shore or on the lightship, which is kept charged by an engine. The United States tested five of these bells for 51 days of continuous ringing (at intervals of 6 seconds) in 1906; their introduction into England had been slow, although the Admiralty had reported favorably on them in 1906. For use on the sea floor the bell is generally provided with electric power, and suspended from the apex of a steel tripod, 25 feet high and weighing 3 tons, down to depths of 25 fathoms (at the Stack Lighthouse, Holyhead, *e. g.*). The ordinary submarine bell-buoy is operated by the waves in the way above indicated; the whole mechanism is housed in a boiler plate receptacle beneath the buoy, which is open below, only the bell itself protruding; thus the mooring chain cannot foul the bell or its mechanism.

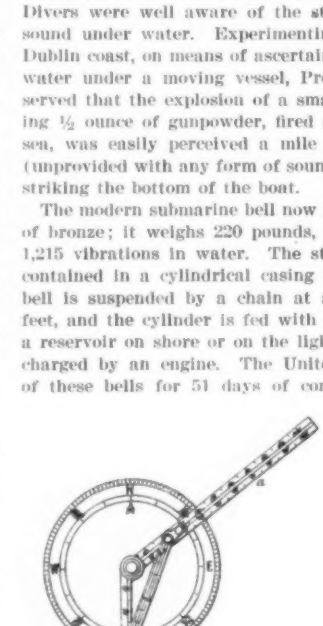


Fig. 1

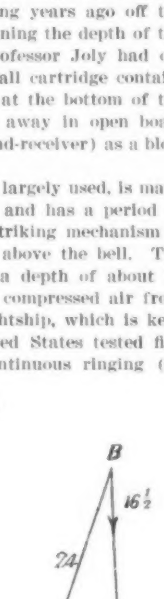


Fig. 2

The Joly collision predictor, and the principle on which it operates

Passing to sound-receiving devices on board, Professor Joly said that at first these devices had been towed astern or been attached to the outside of the ship; but it had been found that listening to the acoustic vibrations which the ships' walls picked up from the sea was most effective. A small cast-iron tank was screwed to the inner wall which formed one of the sides of the tank; this tank should be low down in the water. The tank was filled with water, and two microphones were immersed in it, one more forward than the other; there was one tank on each side. Wires from the microphones passed up to the bridge, and the two receivers, one on each ear, were connected with the fore and the aft microphone of the same tank; by means of a switch the observer listened alternately to the microphones on the port and on the starboard. When the source of sound was right ahead, both telephones would speak equally loud; when the sound came from the port side, that sound would predominate; when the sound came from aft, the telephones would not respond except at close distance; that was partly due to the disturbance of the water by the propellers. To ascertain the bearing of the bell more clearly the ship was swung. The best position for the tanks was forward in the bows; but it depended upon the ship lines, and the most suitable position was determined by experiment.

Though the combination of submarine signals and radiodots was the least liable to failure, it was not the most sensitive method, and its use was practically restricted to large high-speed vessels which required to determine their position within half a mile or less. If the dots were sent at intervals of 0.6 second, the bell stroke would lag by the interval between two dots for each half mile traversed. Five miles off the coast, the lag would amount to 10 intervals, the bell coming in with the eleventh dot; estimates within a quarter mile would be possible. In these cases the observer listened with one ear and one telephone to the bell, and with the other to the dots.

Professor Joly then referred to the interesting experiments on synchronised signals—hardly known in this country, he remarked—which the United States Hydrographic Department had conducted in September, 1911. From the Nantucket Shoal Lightship (east of New York) three signals were given simultaneously once every minute: a steam whistle W, a submarine bell-stroke B, and radiodots, or ticks (lasting 2 seconds or 3 seconds) R. The signals were received on the cruising steamer Washington, the interval between B and R being determined within a few tenths of a second by a Hack chronometer, and the W-R interval within half a second by a stop watch; from these observations the position of the Washington was deduced assuming the velocity of sound in air to be 1,132 feet (at the air temperature 68.5 degrees F.) and in water (at 66 degrees F.) to be 4,794 feet per second; the weather was calm and hazy with light airs from west-north-west. The true course of the ship was further determined by rangefinder, compass, and log; a tidal current northward was allowed for. The Washington first steamed due west for 8 miles, turned and headed east-south-east, passing the lightship on the port beam at a distance of 3,450 yards, went on in the same direction for 8 miles further, then turned north-west, passing the lightship again on the port beam at 4,600 yards, and then turned finally south-east back to the station. On this course, with the station at first right astern, the whistle was lost at ½ mile (zone of silence?), the bell at 2 miles from the station; the bell was picked up again as soon as the ship had turned east-south-east, at 7.6 miles, the whistle only when the ship was once more within 4 miles of the station; 5½ miles from the station the bell was lost again, the station being then astern, 19 degrees off the course, while the whistle remained longer audible this time, within 7½ miles from the station. On turning north-west the bell was at once picked up again at 8.6 miles from the station, the whistle only at 6 miles; afterwards both the acoustical signals remained audible throughout. The track of the Washington as deduced from these observations, forms a curious zig-zag line, sometimes on the one, sometimes on the other side of the true course, but on the whole fairly correct, though in one extreme case the distance deduced from the whistle and the bell differed by nearly 1 mile.

It was found thus that the submarine bell sound carried further than the aerial whistle sound and was not subject to capricious irregularities, but that the submarine signal was badly received from astern with the microphone tanks forward in the bows. The Hydrographic Department was satisfied with the experiments, and the Fire Island Lightship, off New York, was fitted up for three synchronous signals as indicated. There was one modification, however; the bell-stroke preceded the first radiodot by 0.6 second. Thus a listener at half a mile distance heard both the signals together, and if he counted 10 radiodots before hearing the bell, he was 10 half miles off; that was a simplification, Professor Joly pointed out, but if the sailor were within half a mile, he would hear the bell before the dot, which was confusing. In a recent report issued by the British Board of Trade it was mentioned that the apparatus of this Fire Island Lightship was operated during fog, mist, rain or snow; that the range was limited to the bell-receiving equipment on board ship, which was practically within 6 miles or 7 miles; that the bell gave 6 strokes, paused, and then 8 strokes, once every 38 seconds. Hence, the lecturer remarked, two unsymmetrical groups of bell-strokes were emitted, probably to facilitate the identification of the station, the lightship spelling out its name by the signals. The size of the antenna was such that the radio-signal range was not much greater than the bell range, to avaid interference with other radio signals.

The oscillator of R. A. Fessenden, the lecturer proceeded, was a rival of the submarine bell of astounding promise. It acted both as transmitter and receiver, it had a range of 30 miles and more, could convey Morse

*From *Engineering*.

signals to these distances, allowed of determining the depth of the water beneath the moving ship and the location of icebergs by reflected sounds, and seemed even to be utilisable as a telephone over short but useful distances. The Fessenden oscillator, as well as the H. C. Berger apparatus (in which longitudinal vibrations are emitted by a wire), were noticed in the issue of *Engineering* of April 16, 1915 (page 438) in connection with a paper read by J. B. Millet and F. L. Sawyer before the Society of Naval Architects and Marine Engineers at New York. The Fessenden oscillator may briefly be described as a powerful electromagnet on an alternating circuit (500 periods per second), in the cylindrical pole gap of which a copper cylinder, 9 inches in diameter, moves endwise to and fro; the cylinder is connected with the oscillating diaphragm, which may be part of the ship's side, the moving parts weighing more than 100 pounds. The practical audibility ranges stated at the New York meeting to have been attained in the first experiments were smaller than the 30 miles claimed by the Submarine Signal Company, as Professor Joly mentioned. But improvements had been effected, and there were certainly new possibilities as regard synchronous signalling.

With the aid of this oscillator a ship steaming at 25 knots might ascertain her distance from the land and the bearing of the signal station, and thus her right course, more than an hour before making port, in any state of the atmosphere, and it could further find out in what depth of water she was moving, and whether there were any icebergs near. For this purpose a commutator with one conducting segment was combined with the oscillator; two brushes bore against the commutator, the one being joined to the alternating generator, the other to the telephone receiver. As the commutator revolved, the oscillator was momentarily excited; the sound travelled to the bottom of the sea, was reflected back and, acting on the oscillator, generated current in it; this current was heard in the telephone when it happened to be in circuit at the instant the reflected sound came up; the setting of the telephone brush would thus determine the depth of the water. In 8 fathoms the echo would take 1/40 second to come up, and this echo was, in the experiments, heard without the use of the receiver. In other experiments the distance of an iceberg 450 feet long, 150 feet high, was determined by echo while the United States revenue cutter used in the trials kept within distances ranging from 0.5 mile to 2.5 miles of the berg. The echoes were sufficiently loud at 2½ miles to be heard all over the ship, although the oscillator was not properly installed, but only lowered overboard.

These wonderful achievements, Professor Joly continued, seemed even to be surpassed by those secured with the aid of the radiophone at Point Judith, at the western approach to Narragansett Bay, Rhode Island. A phonograph, started by a switch, called out the name of the station every 5 seconds; after three repetitions a much feebler voice uttered the warning: "You are getting closer, keep off." The receiving apparatus, the Submarine Signal Company had informed the lecturer, was very small and required so little tuning, that a few minutes' instruction sufficed for its use by inexperienced men; the sailor would first hear the "Point Judith," and then the warning. With the aid of radiophone stations and, further, of radiogoniometers (wireless compasses) for the determination of the direction in which the sound arrived and thus the bearing of the station, a ship would be able to proceed from headland to headland without seeing any lights. These radiosignals, which were only meant for a limited range, and especially the radiogoniometer, were, however, affected by atmospheric conditions.

Dealing in his second lecture with the prevention of collisions at sea, Professor Joly remarked that he did not wish to abrogate the old-established methods of whistling and listening, nor the old rules as to the right of way and slowing down in thick weather. But submarine signalling, the radiogoniometer (*e. g.*, the Bellini-Tosi directive transmitter) and radiotelephony had placed means at our disposal, by the aid of which good speeds might be maintained at sea, and the time had come for a complete reconsideration of the problems. As a first essential condition the future Board of Trade would have to require that a continuous watch be kept in the wireless room during thick weather on all ships. The operator should send and receive signals, the officer of the watch interpret and direct them; that division of duty would contribute to safety. The submarine signals could be given by bell (to be placed in a recess in the ship's bottom) or by oscillator; low power radiosignals he would suggest, should be emitted at intervals of 5 minutes. Two ships, A and B, approaching one another, would exchange code signals giving course (in degrees, counted clockwise) and speed; thus A, steaming 53 degrees (about east-north-east) at 11 knots, would learn that B was going 180 degrees (south) at 16½ knots. A and B could only collide if simultaneously reaching point 0 (Fig. 2), and the conditions of a possible collision might be characterised by (1) the danger bearing, (2) the danger rate of approach, (3) constant bearing, (4) constant rate of approach. In the case mentioned a collision could only occur when B was bearing about north-north-east from A, and A south-south-west from B, and if they approached one another at the rate of 24 knots. Hence by observing the actual bearing and actual approach, A could tell whether a collision was likely, and in most cases A would at once know that no collision was to be feared. The three factors involved were position, speed, course, and the distance between the ships would decrease at the maximum rate possible if a collision were to occur. The rate of approach was the third side of the triangle A B 0, which the sailor could determine, without geometrical construction, by the aid of Professor Joly's "collision predictor."

This predictor (Fig. 1) consisted of a circle upon which compass bearings were marked and which carried two limbs, *a* and *b*, pivoted at the centre and divided in knots; on a cursor slipping along *a* was further pivoted the arm *c*, which was provided with a transparent scale. The sailor set *a* to the course of his ship A, *b* to the course of B, then moved the cursor along *a* up to the division marking his speed, and inflected *c* until it intersected *b* at a distance (on *b*) proportional to B's speed; he had then constructed his triangle, and could read off the maximum velocity (danger rate of approach) of 24 knots on *c*. In order to facilitate the estimates, *c* was graduated to mark the amount by which A and B approached within 2 minutes, that being the interval separating the distance observations by synchronous signalling; in the case considered that rate of approach would be $24 \times 2/60 = 0.8$ sea mile in 2 minutes. The direction of *c* at the same time gave the danger bearing, better to estimate which a parallel motion up to the centre could be imparted to *c*. Held in the true compass position, the direction in which *c* was pointing told A in what direction B was approaching and also the distance separating the ships and the time taken to cover that distance—as if A were watching the approach of B on a chart.

When A felt uncertain about his determinations, he signalled to B that he was going to determine the distance; B then prepared to listen, picked up A's bell, and told A his distance; if that distance were 5 miles, they would both know that they could only collide after 12 minutes (the approach being 0.8 miles in 2 minutes). If repeated signalling after 2 minutes indicated 4 miles, there was danger. These observations, and the times still to go were entered on a sheet and compared with the danger distances (from the predictor); if they agreed, there was danger. Collision could only occur with conditions maintained when the rate of approach was constant; that constant rate could also be made a criterion of danger (4), as could likewise be the fact that the bearings remained constant (3).

But there were serious objections to the constant bearing method, whether relying on the radiogoniometer or on submarine signals. The ship's course had to be altered during these hurried observations; the ear estimate of the intensity of sound was always deceptive, and though the Bellini-Tosi directive transmitters had much been improved and readings within 1 degree were claimed, there seemed to be little variation in the maximum intensity of current over a range of 10 degrees from the direction of the signal. The fourth criterion, the constancy of the rate of the approach, did not involve knowledge of course and of speed; it required periodic emission of synchronous signals by A which B received, reporting the distance deduced; if the rate of approach diminished, the danger was past. If a third vessel C came within the range of audition while A and B were exchanging signals, C should keep out until A and B were clear, not to confuse their signals by her own; C might be restricted to acoustic signals, Professor Joly suggested.

All these methods, would, of course, have to be thoroughly tested before adopton. Other improvements in radiotelephony might further reduce the risk of collisions. By phonograph a vessel might call out her name as a distinguishing signal, and also her course and speed, when occasion arose. Professor Joly did not disguise the eccentricities of radio signals, which may be heard at astounding "freak" distances or may become almost indistinguishable at small range. He ignored one difficulty, however, that of language. Phonographs generally speak with a peculiar accent; we do not pretend to know what a Spaniard, *e. g.*, might understand, when "Point Judith" was shouted at him in American. But sailors somehow manage to understand one another, and the manysided difficulties will be met as they have been under other conditions.

The Metallurgy of Copper

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by such low temperature as 265° C. On examination of the curve it will be noticed that the copper hardened by cold-work begins to lose its hardness quite rapidly at this temperature until a perfect anneal, or perfectly soft metal, is reached at a temperature of 600 degrees C. In this respect copper shows more of what might be termed molecular mobility than most metals.

Copper has a very high electrical conductivity, or conversely, a very low specific resistance. All electrical conductivity measurements are based on copper as a standard, its conductivity being valued at 100 per cent. The only other metal having a higher conductivity is silver. On account of its electrical and mechanical properties copper is absolutely essential to electrical construction work, and vast quantities of the metal are used in the electrical industries. The electrical conductivity of electrolytic copper produced today averages 100 per cent. and occasionally runs over 101 per cent. The reason for this is that the standard measurement is based on a determination made some thirty or forty years ago, and known as Matthiesens' Standard. At the time these standard measurements were made, present day refinements in the electrolytic process were unknown, and the purest copper then available was not the equal of the every day production of electrolytic copper at the present time.

Minute traces of impurities in copper affect its conductivity to a remarkable extent. The presence of .05 per cent. tin lowers the conductivity from 100.5 per cent to 95 per cent. This peculiarity affords a very efficient means of determining the purity of a sample of copper, and routine refinery determinations are usually made in this way. The sample is forged to about ¾ inch round, and from there cold drawn to about No. 12 gage and annealed and tested.

Pure copper is malleable in both the hot and cold states, and advantage is taken of this property in the manufacture of copper wire and sheet. For the manufacture of copper wire, wire-bars weighing from 150 to 500 pounds, depending on the size of the wire to be made, are heated in a pre-heating furnace to a temperature of 700-750 degrees C. and hot-rolled down to a diameter of ¾ inch. A wire-bar weighing 250 pounds when rolled to ¾ inch diameter will be over 140 feet long and when cold-drawn to wire 1/16 inch diameter will be over 21,000 feet, or about 4 miles long.

The preliminary hot-rolling operations, or "passes" as they are called, are performed in a hot-rolling mill consisting of a pair of steel rolls about 4 feet long and 16 inches in diameter, having a succession of grooves cut in them which diminish in size from a little less than the dameter of the wire-bar to about 1½ inches diameter. The hot-wire bar is passed through these grooves one after the other, in succession, and after passing through the final groove is then rushed to the finishing mill as rapidly as possible to prevent cooling. The more modern mills are known as "three-high mills," so called because they have three rolls mounted one over the other, the bottom and top roll revolve in the same direction while the middle roll revolves in the opposite direction. The purpose of this type of mill is to eliminate passing the bar around the mill to be passed through the next groove. With the three-high mill the metal is passed through the groove between the bottom and middle roll, and is then passed back through the next groove between the middle and top roll. The old type of mill consisting of two rolls is known as a "hand-round" mill because the bars are passed back to the entry side of the rolls by hand.

The finishing hot-mill is similar to the "hand-round" or "three-high" mills described except that they are much smaller and run at a much higher speed. This mill reduces the bar from about 1½ to ¾ or ⅝ inch. After passing through the finishing groove the wire is coiled on a mechanical coiler and is then ready for the wire mill.

Hot-rolling is very much cheaper than cold-rolling on account of the fact that higher speeds can be used, and no annealing operations are necessary. On account of the metal being at an annealing temperature during the process of rolling the hardening effects of mechanical deformation are eliminated, and the hot-rolled wire is practically as soft as the metal was before rolling.

The process of cold-drawing wire is so well known that description is hardly necessary. Copper wire is ordinarily cold-drawn about 85 per cent. reduction of area between anneals. That is to say, the wire may

be reduced in diameter 85 per cent. before annealing is necessary.

Copper sheets are also hot-rolled from cakes down to about ⅝ or ¾ inch thick, and then cold rolled to finished size. The reason copper wire and sheet are not hot-rolled all the way to finished size is primarily because the diameter and thickness cannot be closely controlled, and the fact that the copper scales excessively while hot causes the finished surface on the hot-rolled wire or sheet to be very rough and dirty. Quite frequently a certain amount of hardness or "temper" is required in the wire or sheet, requiring, therefore, a certain amount of cold work to be performed.

Seamless copper tubing is ordinarily made by cold-drawing a cast copper tube or shell. This casting is made by pouring copper into a tube mold, closed at one end, through the center of which is a collapsible core. The difference between the diameter of the core and the inside diameter of the tube mold will be the thickness of the cast tube or shell. The size of these castings depends on the size of the finished copper tubing required; for small sizes, such as is used for the ordinary household gas water heater, copper gasolene feed pipe for automobiles and motor boats, etc., the casting would be about 4 feet long by 3 inches outside diameter and about 2 inches inside diameter, the wall thickness, therefore, is about ½ inch. Such castings are sometimes poured as large as 7 inches or 8 inches in diameter with a wall thickness of about 1 inch. The collapsible core requires considerable skill to make, or rather to build. It consists of a piece of iron pipe (for the small size of casting, this would be about 1 inch in diameter), pierced with holes over its entire length, these holes are to allow the escape of gas. The pipe is mounted on a core bench so arranged as to allow of its rotation by hand; damp hay is then worked onto the pipe forming a tightly wound layer of about ¾ inch thickness. Moistened French chalk is then spread over the hay forming another fairly thick layer, followed by a lighter coating of graphite; the pipe is kept rotating during these operations of building up the core. When the core is finished it is baked for several days at a temperature of approximately 80 or 90 degrees C.

The purpose of this collapsible core is to allow the tube to be easily extracted from the cast shell when cold. When the copper solidifies in the mold it shrinks considerably and breaks up the chalk composition, allowing the iron pipe and the remains of the core to be easily extracted. A solid metal core cannot be used because it would be impossible to extract it from the shell when cold.

The casting is then "swaged" at one end, which operation reduces the diameter sufficiently to allow this end of the tube to be introduced through the drawing die; after which the casting is ready to be drawn. This is done on a tube drawing bench where the swaged end of the tube is clasped by a travelling jaw, and the tube is pulled through the die over a plug. This operation reduces the outside diameter and also the wall thickness of the tube. A diagramatical arrangement of a tube drawing bench is shown in Fig. 5. The tube is drawn and annealed in this manner until it reaches the finished size.

Another process for making copper tubes, which obviates the necessity for casting a shell, is used to some extent in this country. It is known as the Mannesman process, and was invented some twenty-five years ago by a German who discovered that if a solid bar of metal is pushed through a pair of rolls, both of which revolve in the same direction, the bar will be rolled hollow. A modern Mannesman machine pushes a solid bar of copper through a small pair of rolls onto a mandrel, the bar being rotated at the same time as it is pushed. This operation is carried out at a red heat and gives a copper shell suitable for cold drawing.

Stellar Evolution

(*Continued from page 323*)

form a binary star of short period—a typical type B binary. At the present time Jupiter is too small in mass to be a star. If the sun is now passing through a period in which its mass is decreasing, the mass of Jupiter will be growing, or at the very worst will be stationary, and therefore gaining relatively to the sun. One can fancy the sun decreasing toward extinction while Jupiter is slowly growing toward stellar conditions. In this manner Jupiter and the sun might approach equality in mass. At a later time, if the solar system passed through a region rich in matter the sun and Jupiter would grow equally, and our solar system, if not reduced to two members, at least would present the interesting phenomenon of a system of two dominating suns of approximate equality. In the early stages of this rejuvenation the sun and Jupiter would form a binary star of long period and reddish color. As they grew in mass gathered from surrounding space their colors would brighten, they would draw closer together, and their period would shorten. Since the effect of a resisting medium is to make the orbits circular, it can be shown that the product of the period and the fifth power of the sum of their masses would remain constant during this process of growth, and so also would the product of the mean distance and the cube of the sum of the masses remain constant. In other words, the period would vary inversely as the fifth power of the sum of the masses, and the mean distance inversely as the cube of the sum of the masses. If the masses of the sun and Jupiter were increased by gathering in atomic material to five times their present masses, the distance of Jupiter would be reduced from 500,000,000 miles to 4,000,000 miles, and its period would be reduced from about twelve years to approximately thirty-three hours. If the masses were of approximate equality their spectra would change in the direction from type M toward type B, and if their masses were sufficiently great to have a spectrum of type B we should certainly have a short-period binary with the circular orbit which is characteristic of this class of spectroscopic binaries. On the other hand, if we follow such a binary in our imaginations as through the ages it decreases in mass, we see the reverse process taking place, the distance between the stars increasing and the eccentricity increasing likewise, but the temperature decreasing and the color tending through the yellow toward the red until we see finally a typical visual binary.

An indefinite prolongation of a star's life undoubtedly would vastly increase the significance to be attached to a close approach of two stars, since such a close approach is merely a matter of sufficient time. With the relatively short span of life hitherto assigned to a star such an event is highly improbable until many aeons after the star has become cold and dead. The approach of two cold and solid stars would certainly have to be extremely close to have any further effect on the stars than to change their speeds and their paths, and it is very doubtful if anything short of actual collision would disrupt them. A quite different state of affairs would arise, however, if the stars were massive, and very hot and active. These are the conditions postulated in the planetesimal hypothesis, and the consequences of such conditions must play a very common rôle in the life-history of the stars. From the consequences in the sun-Jupiter system, in which it has been shown how Jupiter might become as massive as the sun and the sun become a binary star, a possible mode of genesis of these interesting objects is obtained. An extension of the planetesimal hypothesis seems quite competent to account for the existence of many binary stars, from the typical yellow, visual binaries of high eccentricity and long period to the typically short-period, white binaries of spectral type B with their almost perfectly circular orbits. The coalescence of the many members of a planetary system into a system of two or three members would furnish many occasions for the flashing up of a star into an intense but temporary brilliance, such as is exhibited in the relatively frequent temporary stars. It is not necessary, however, to suppose that all binaries are formed in the same manner, for it is quite conceivable that if a nebula has two centers of condensation a binary of long period and high eccentricity should result through the process of condensation. It is quite possible too that there exist other processes which have not yet been formulated.

Two processes are here recognized by which a star comes into existence. The first is a *possible* condensation from a nebula, though this does not seem to be as inevitable a process as it has generally been regarded. The second is the growth of a nucleus—a fragment perhaps from some disrupted mass, a witness of some titanic cataclysm—by the accretion of atoms and small particles to such a mass that the release of subatomic energies transforms it into a radiating star. By collision, or *very* close approach, only can we account for a star passing out of existence, in the first of which two masses are united into a single one, and in the second a single solid mass is disrupted into many fragments. But during the continuance of its existence a star is essentially a singular point in an infinite field of energy. Through these singular points the energy ebbs and flows. When the flow exceeds the ebb the star grows in mass and radiating power and character of spectrum. When the ebb exceeds the flow the star declines in mass and radiation, at times even to the point of extinction. But even during the period when its radiation fails, the singular point persists, and through it again flows the tide of energy when the conditions are suitable. Just as the atom and the molecule are permanent forms of physical existence, so also is the star a permanent form of physical existence notwithstanding that the individual may pass from birth to its dissolution. There is no necessary limit to its age, and though the star itself may rise and fall, the universe as a whole is not essentially altered. The singular points may change their positions and their brilliancy, but it is not necessary to suppose that the universe as a whole has ever been or ever will be essentially different from what it is today.

Industrial Substitutes in Germany

SINCE April, 1915, no cotton has been used in the manufacture of smokeless powder in Germany, its place being taken by cellulose obtained from German woods. Camphor, which up to seven years ago was imported from Japan, was then replaced by a product made synthetically from American oil of turpentine, but when the importation of this oil was stopped, the whole of the camphor required for explosive purposes was prepared from German materials. It is claimed that the new synthetic product is cheaper and better than that derived from oil of turpentine.—*Weltwirtschaft Zeit.*

SCIENTIFIC AMERICAN SUPPLEMENT

Founded 1876

Published by Scientific American Publishing Co.

New York, Saturday, May 24, 1919

Munn & Co., 233 Broadway, New York

Charles Allen Munn, President; Orson D. Munn, Treasurer
Allan C. Hoffman, Secretary, all at 233 Broadway

The Scientific American Publications

Scientific American Supplement (established 1876) per year $5.00
Scientific American (established 1845) 5.00
The combined subscription rates and rates to foreign countries, including Canada, will be furnished upon application.
Remit by postal or express money order, bank draft or check.

Scientific American Publishing Co.

233 Broadway, New York

The purpose of the Supplement is to publish the more important announcements of distinguished technologists, to digest significant articles that appear in European publications, and altogether to reflect the most advanced thought in science and industry throughout the world.

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